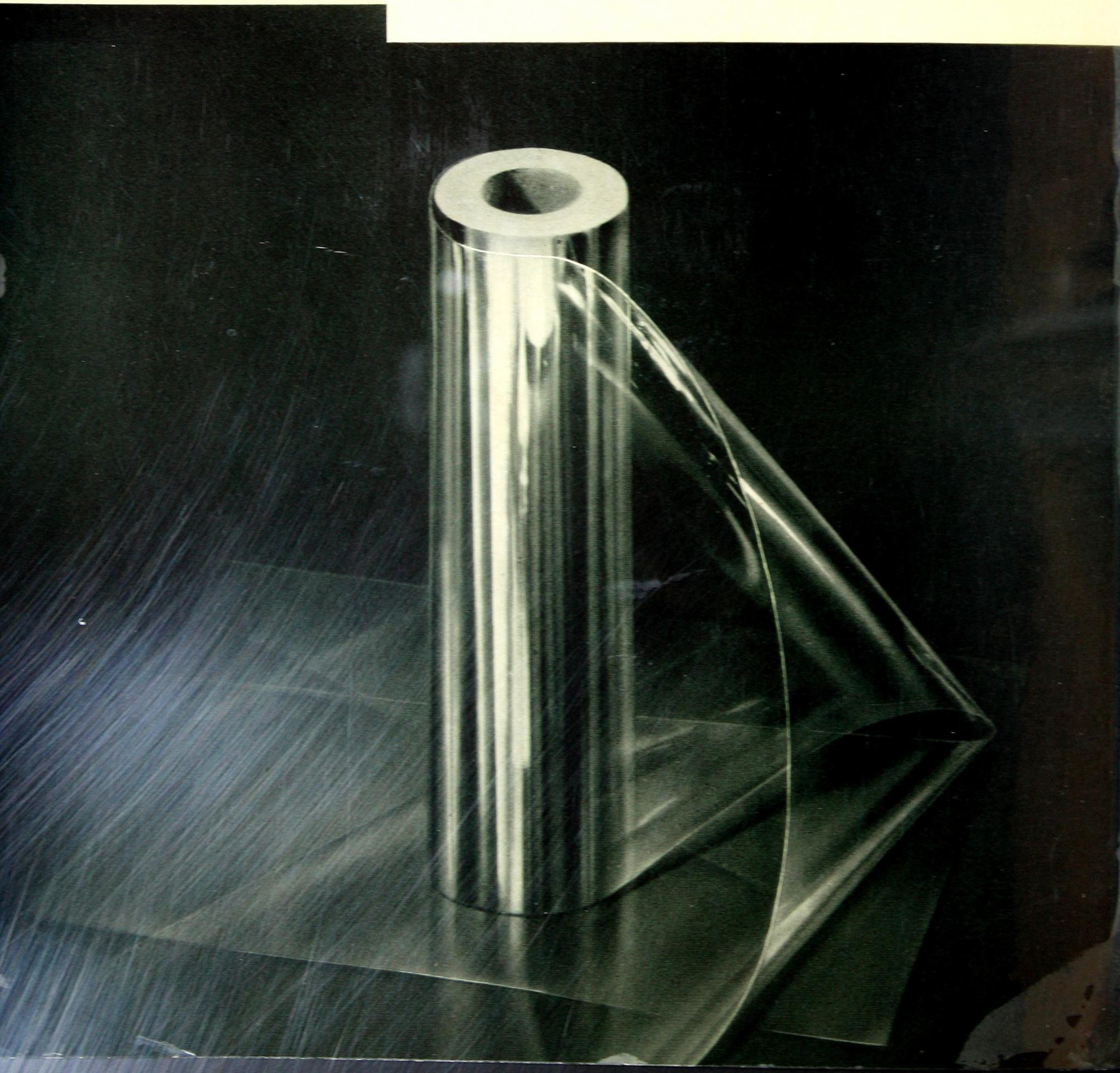
PROPERTIES OF KODAPAK SHEET

PROPERTIES OF

Kodapak Sheet



A report on the basic properties and performance data of this versatile cellulose ester, thermoplastic material

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CELLULOSE PRODUCTS SALES DIVISION

EASTMAN KODAK COMPANY · ROCHESTER 4, N. Y.

SUMMARY OF TYPES, GAUGES, AND FINISHES OF KODAPAK* SHEET

TYPES

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Kodapak II Sheet—Cellulose Acetate Butyrate

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M—Medium Gauges—0.003″ to 0.020″

FORMULATIONS

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F116—L and M gauges
F120—L gauges
F122—M gauges
F124—M gauges

KODAPAK II SHEET

F208—L gauges
F268—L gauges
F298—L gauges

COLORS AND FINISHES

KODAPAK I SHEET

CLEAR TRANSPARENT
0.00088″ (No. 88)
0.00100″ (No. 100)
0.00120″ (No. 120)
0.00150″ (No. 150)
0.00200″ (No. 200)
0.003″
0.005″
0.0075″
0.010″
0.015″
0.020″

MATTE
0.003″
0.005″
0.0075″

COLORED TRANSLUCENT
0.003″ Currently available in white, ivory, peach, blue, green, pink, yellow, and orchid.

Special
GUMMED KODAPAK
0.00120″ (No. 120)

KODAPAK II SHEET

CLEAR TRANSPARENT
0.00090″ (No. 90)
0.00110″ (No. 110)
0.00130″ (No. 130)
0.00160″ (No. 160)
0.00200″ (No. 200)

WHITE TRANSLUCENT
0.00160″ (No. 160)

*The trade name, "Kodapak," formerly applied only to gauges 0.002″ or less, is now used to designate the thicker gauges as well. The trade name "Eastman Acetate Sheet" has been discontinued.

Kodapak Sheet

Kodapak Sheet is a thermoplastic cellulose ester material. It is made in two types, *Kodapak I*, cellulose acetate, and *Kodapak II*, cellulose acetate butyrate. Kodapak I is made in a complete range of gauges from 0.00088″ up to 0.020″, but Kodapak II is made only in the light gauges up to 0.002″. (See detailed list of gauges, page 2.)

Kodapak Sheet can be readily formed by means of heat and pressure, is easily creased, beaded, cemented, dielectrically heat sealed, and fabricated by standard methods.

Kodapak Sheet is manufactured by casting from solvents under the same rigid conditions of purity and cleanliness as Kodak photographic film base. This accounts for Kodapak's outstanding optical clarity and brilliance, as well as its uniform physical characteristics. Kodapak Sheet has excellent permanence, and mechanical, thermal, chemical, and electrical properties which recommend it for a wide variety of applications.

Kodapak I, cellulose acetate, is a general-purpose sheet with more rigidity and higher heat resistance than Kodapak II and is preferred in the rigid packaging and some decorative fields. *Kodapak II*, cellulose acetate butyrate, has lower moisture absorption, higher stretch, and greater toughness than Kodapak I. These characteristics make Kodapak II particularly suited for electrical insulation, wrapping, and certain textile applications.

The tables and charts in this booklet are presented as an aid in the selection of the most suitable Kodapak Sheet for any particular application. The data were obtained in Kodak laboratories using either the standard tests for plastics of the American Society for Testing Materials, or, in some cases, special tests designed for a particular purpose as described on pages 18 and 19. All figures given, however, should be considered only as average or typical. Individual samples may vary somewhat, as a certain manufacturing tolerance is necessary.

KODAPAK FORMULATIONS

Kodapak I Sheet

Kodapak I Sheet is made in several formulations which may be used interchangeably for many applications, although some formulations are preferred over others for certain types of work.

While each gauge may not always be available in all formulations, the standard thicknesses are being produced in one or more of the types described:

F103 (Rigid)—This is the most rigid type of Kodapak in the medium gauge range. It has good heat resistance and high strength, and is recommended for general fabrication. It is excellent for shallow drawing and embossing, but is not recommended for deep drawing or vacuum forming. For all forming operations, higher temperatures are required than with other Kodapak formulations.

F116—This is an excellent general-purpose sheet, and is suitable for all types of formed and drawn parts. It is somewhat softer than the other Kodapak formulations, can be worked at temperatures 30° to 40°F. below those required for F103, and is especially recommended for deep drawing.

F120—(Rigid)—This formulation is made only in the light gauges and is recommended where stiffness and low shrinkage are desired.

F122—This sheet is midway between F103 and F116 in softness, has the lowest shrinkage and is recommended for the majority of applications. It is suitable for all container uses, is excellent for medium drawing, and is recommended especially for vacuum forming. Best results are obtained with a temperature 15° to 20°F. below that required for F103.

F124—This formulation is very similar to F122, except that it is not quite as low in shrinkage. It is a supplementary stock, supplied when F122 is unavailable.

Kodapak II Sheet

KODAPAK II SHEET is currently made only in the light gauges and in three formulations:

F208—This is the standard Kodapak II formulation. It has good plasticizer retention and low shrinkage.

F268—This formulation may be interchanged with F208 or F298 for many applications, although it has a somewhat higher shrinkage. It is supplied when F208 or F298 is unavailable.

F298—This formulation has the same properties as F208.

SPECIAL FORMS OF KODAPAK SHEET

In addition to the clear transparent Kodapak, there are several other types of Kodapak Sheet, made in certain gauges (see page 2), for special purposes.

Matte Kodapak I Sheet is the same as the clear transparent material except that one surface is treated to give a translucent matte finish. It is used for drawings and map overlays, for printing, for lamp shades and table mats, for making Christmas cards, and for many other similar applications.

Colored Translucent Kodapak I Sheet has a dull surface pigment application on one side, and is available in a variety of attractive pastel colors—white, ivory, peach, blue, green, pink, yellow, and orchid. It is used in pleated form for making lamp shades.

Gummed Kodapak I Sheet is a clear transparent Kodapak Sheet with a water-sensitive adhesive on one side. Printing in reverse may be applied to the side opposite the adhesive. The sheet is then dipped in water and squeegeed onto glass leaving all but the printing invisible. It is used for signs in store windows, show cases, etc.

White Translucent Kodapak II Sheet is intended primarily for wire winding in electrical insulation applications. It is preferred to the transparent Kodapak Sheet in some cases because it is easier to see whether or not the insulation is properly stripped for soldering.

PROPERTIES OF KODAPAK SHEET

EFFECT OF MOISTURE

The moisture content of cellulose ester sheets, in common with paper and many other materials, varies with the *relative* humidity (not the *absolute* humidity) of the surrounding air. Since most of the physical and electrical properties of cellulose ester sheets vary with the moisture content of the material, it is frequently useful to know just what these moisture relationships are.

The moisture content of Kodapak Sheet at various relative humidities compared with a typical paper is shown by the curves in Figure 1, page 5. At any given relative humidity, Kodapak I (cellulose acetate) holds only about one third as much moisture as paper. Hence, Kodapak I is much more resistant to water. Kodapak II (cellulose acetate butyrate), in turn, holds only about half as much moisture as Kodapak I, at any given relative humidity. The amount of moisture absorbed when Kodapak Sheet is immersed in water for 24 hours is given on pages 16 and 17. The low moisture absorption of Kodapak II makes it superior for all electrical applications.

When cellulose ester sheets absorb moisture from the air, they expand, and when they lose moisture, they contract. This is a purely temporary and reversible dimensional change. The linear expansion of Kodapak Sheet with increasing relative humidity is illustrated in Figure 2, page 5. These curves are almost straight lines between 20% and 70% relative humidity, and humidity coefficients of linear expansion calculated in this range for each Kodapak formulation are given on pages 16 and 17. It is noteworthy that the humidity expansion of Kodapak II is only half that of Kodapak I.

It is often desirable in some converting operations such as controlling register in printing, for example,

Although a container made of Kodapak Sheet will hold water, the material is not moisture vapor proof.

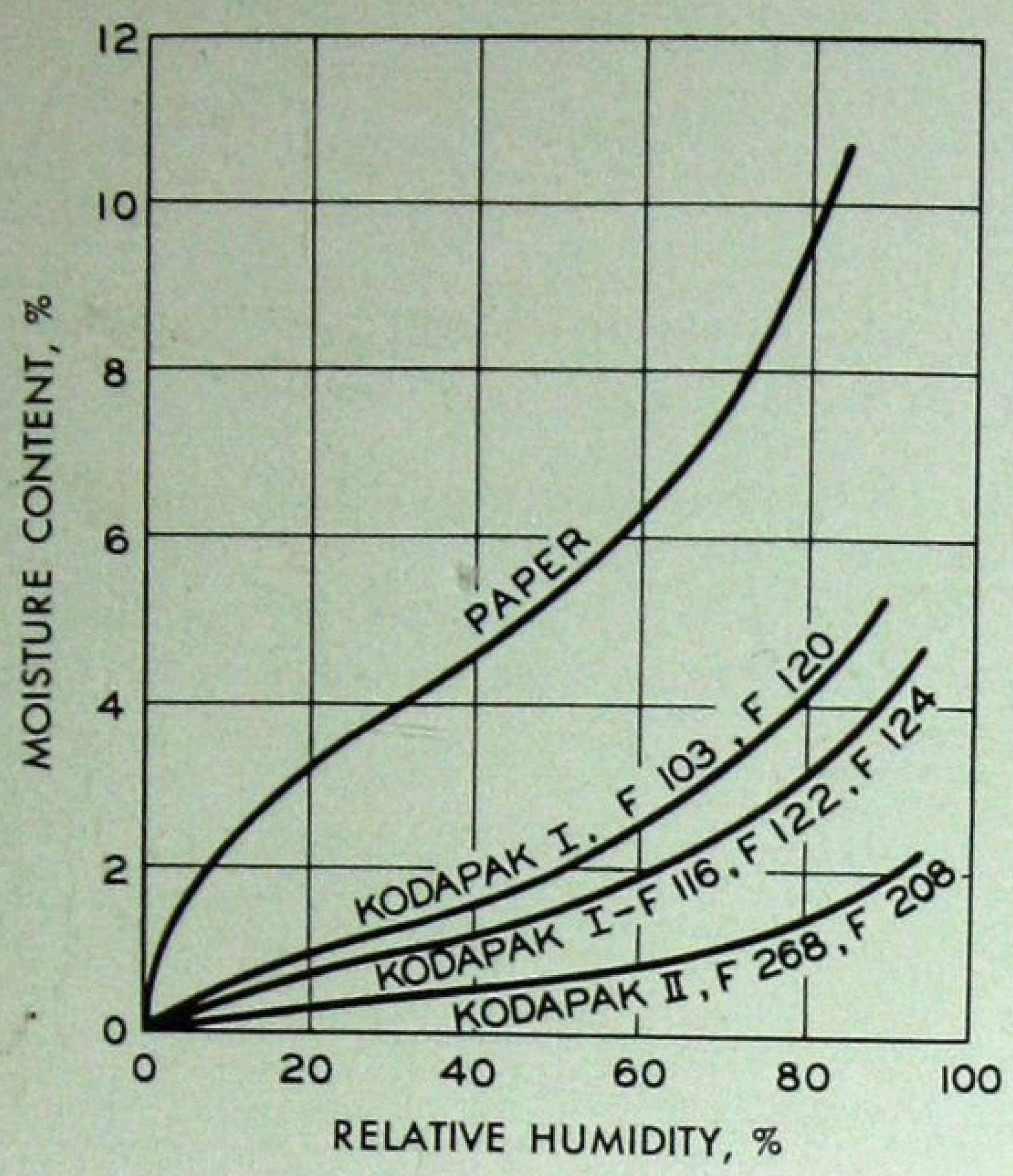


FIGURE 1—Equilibrium Moisture Content of Kodapak I Sheet and Kodapak II Sheet, Compared with a Typical Paper at Various Relative Humidities at 70° F.

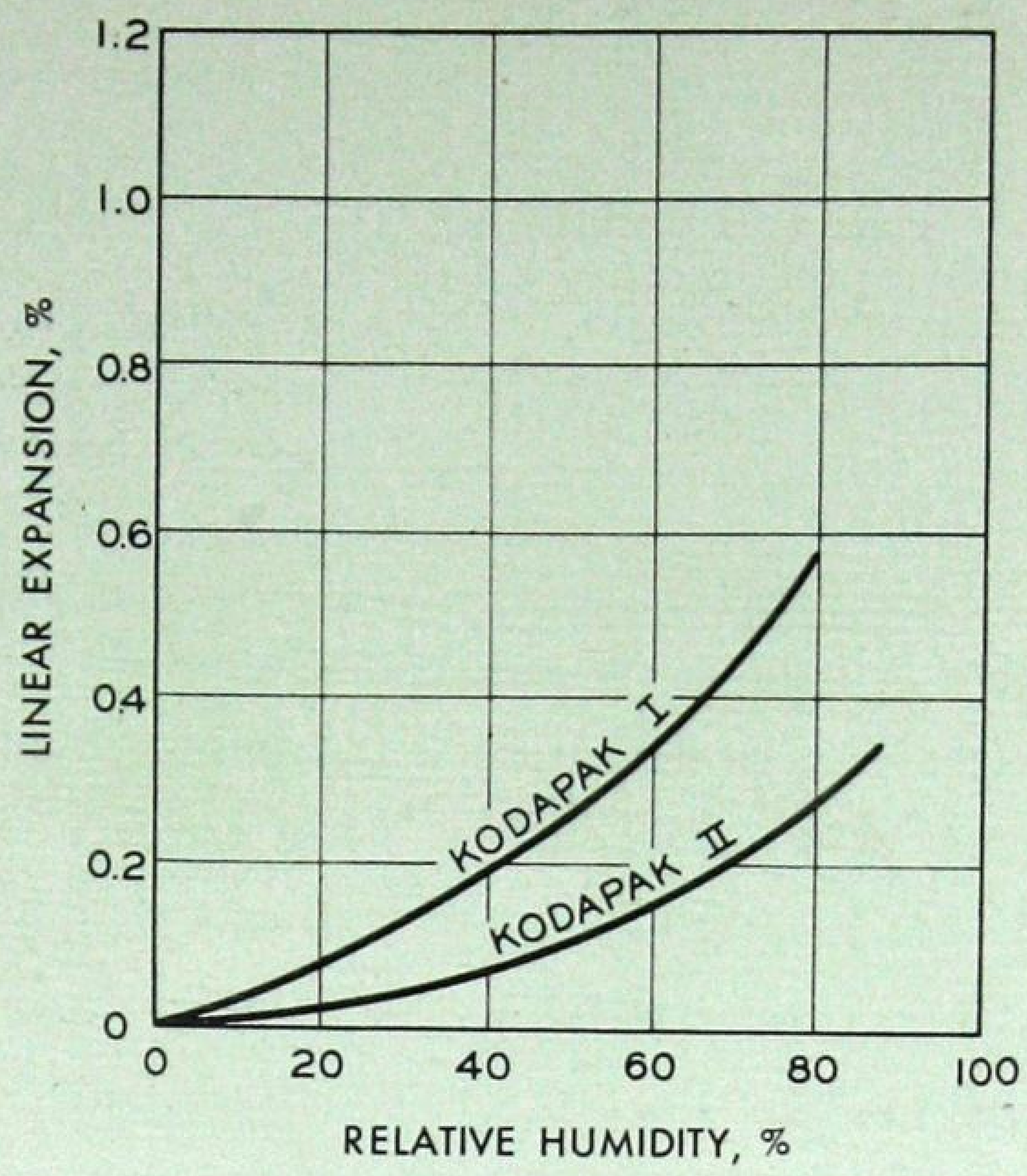


FIGURE 2—Linear Expansion vs. Relative Humidity—Kodapak I Sheet and Kodapak II Sheet at 70° F.

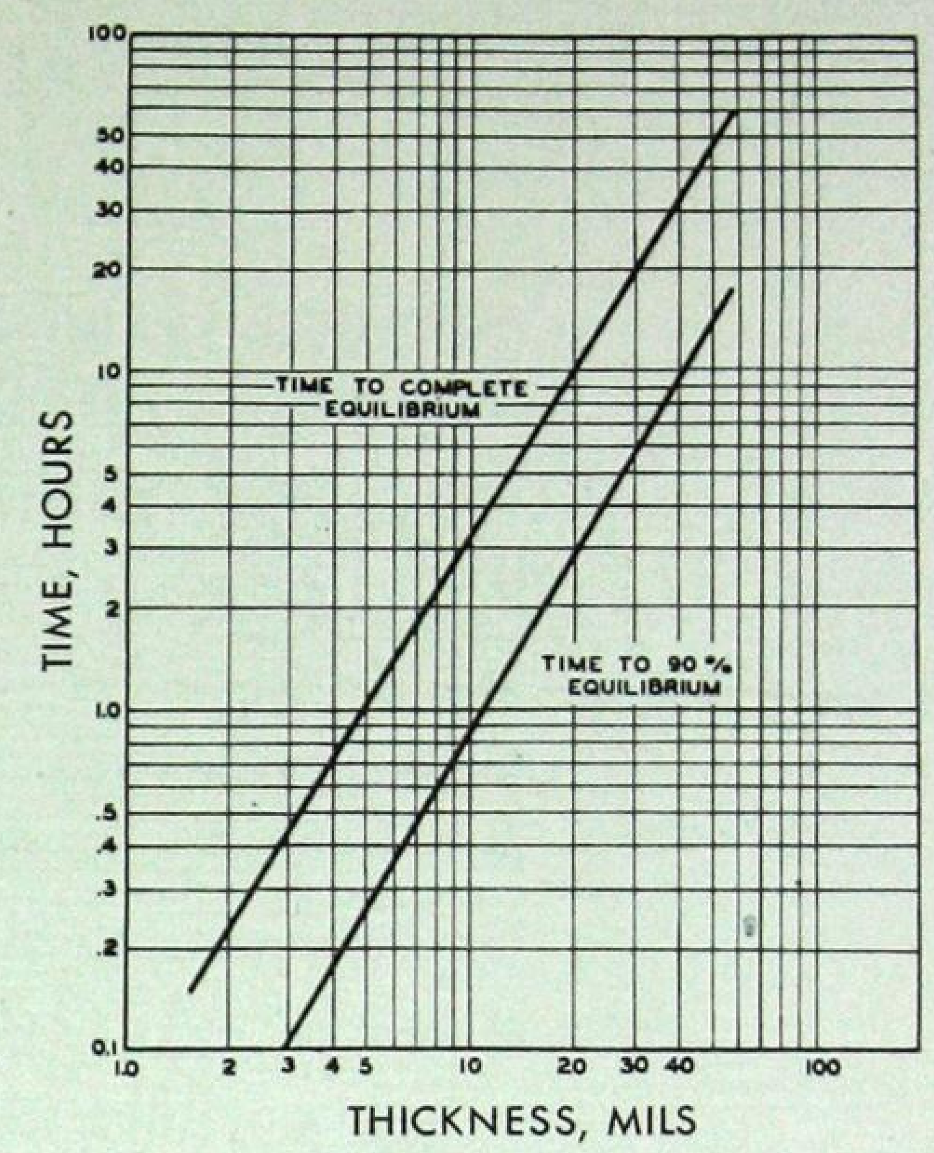


FIGURE 3—Effect of Thickness on the Rate of Conditioning of Kodapak Sheet from 20% to 70% R.H. at 70° F. Air Velocity Approximately 1 Foot per Second.

to dry or humidify Kodapak Sheet. This cannot be done with Kodapak Sheet in the form of rolls or stacks of sheets. The individual sheets must be freely exposed to circulating air. The time required for Kodapak Sheet of various thicknesses to condition from one relative humidity to another is given in Figure 3. These data were obtained on changing from 20% to 70% relative humidity, but the rate of conditioning for a given thickness will not differ greatly for other humidity intervals.

Kodapak Sheet is not appreciably affected by water and may be used as protection against liquid water penetration. For example, a container made of Kodapak Sheet will hold water. However, Kodapak Sheet is not moisture vapor proof. Data on the moisture vapor permeability are given on pages 16 and 17. The rate of moisture vapor transfer decreases with increase in thickness of the sheet, but Kodapak Sheet under no condition provides a complete moisture vapor barrier.

PERMANENCE PROPERTIES

Kodapak Sheet is an extremely stable material chemically and has excellent resistance to discoloration by the ultraviolet rays of sunlight. Most Kodapak formulations likewise have good weather resistance and do not become seriously embrittled on exposure out of doors. In this particular respect, Kodapak II is superior to Kodapak I.

The permanence of cellulose esters is illustrated by the use of safety base photographic film for microfilming archival records. For the same reason, valuable paper documents are frequently laminated between two sheets of cellulose acetate as an aid in preservation.

Kodapak Sheet, in common with most plastic materials, undergoes a certain amount of shrinkage with age. This permanent shrinkage should not be confused with dimensional changes resulting from moisture loss or temperature change since both of these effects are temporary and reversible. Permanent shrinkage of cellulose acetate or cellulose acetate butyrate sheet is caused by the loss of small amounts of solvent remaining after manufacture, gradual diffusion and evaporation of small amounts of plasticizer, or by the release of mechanical strain.

The approximate shrinkage of each Kodapak formulation in specified gauges for three different storage conditions is given in the table, pages 16 and 17. Of the Kodapak I formulations, F120 and F122 have the lowest shrinkage, and F116 the highest. The former are therefore recommended in applications where minimum shrinkage is desired. In the case of Kodapak II Sheet, F208 and F298 have lower shrinkage than F268 and are preferred for that reason for some applications. The approxi-

mate rates of shrinkage of several of the Kodapak formulations for sheets freely exposed to the air at 70°F., 50% relative humidity, are illustrated for 0.001″ gauge in Figure 4, page 6, and for 0.0075″ gauge in Figure 5. The shrinkage of Kodapak I Sheet of various gauges in 3 months at 70°F., 50% relative humidity, is illustrated in Figure 6. Shrinkage occurs more slowly, of course, if the material is stored in rolls or stacks, or if it is protected by a closed container while in storage.

Both heat and moisture accelerate the shrinkage of cellulose plastics. The effect of temperature on the shrinkage of Kodapak Sheet is illustrated for 0.001″ gauge in Figure 7 and 0.0075″ gauge in Figure 8. When cellulose ester plastic sheets in the form of either stacks or rolls are stored in too warm an area, the edges tend to shrink more rapidly than the interior. This sometimes causes sheets to buckle. For this reason, stocks of Kodapak Sheet should not be stored at elevated temperatures.

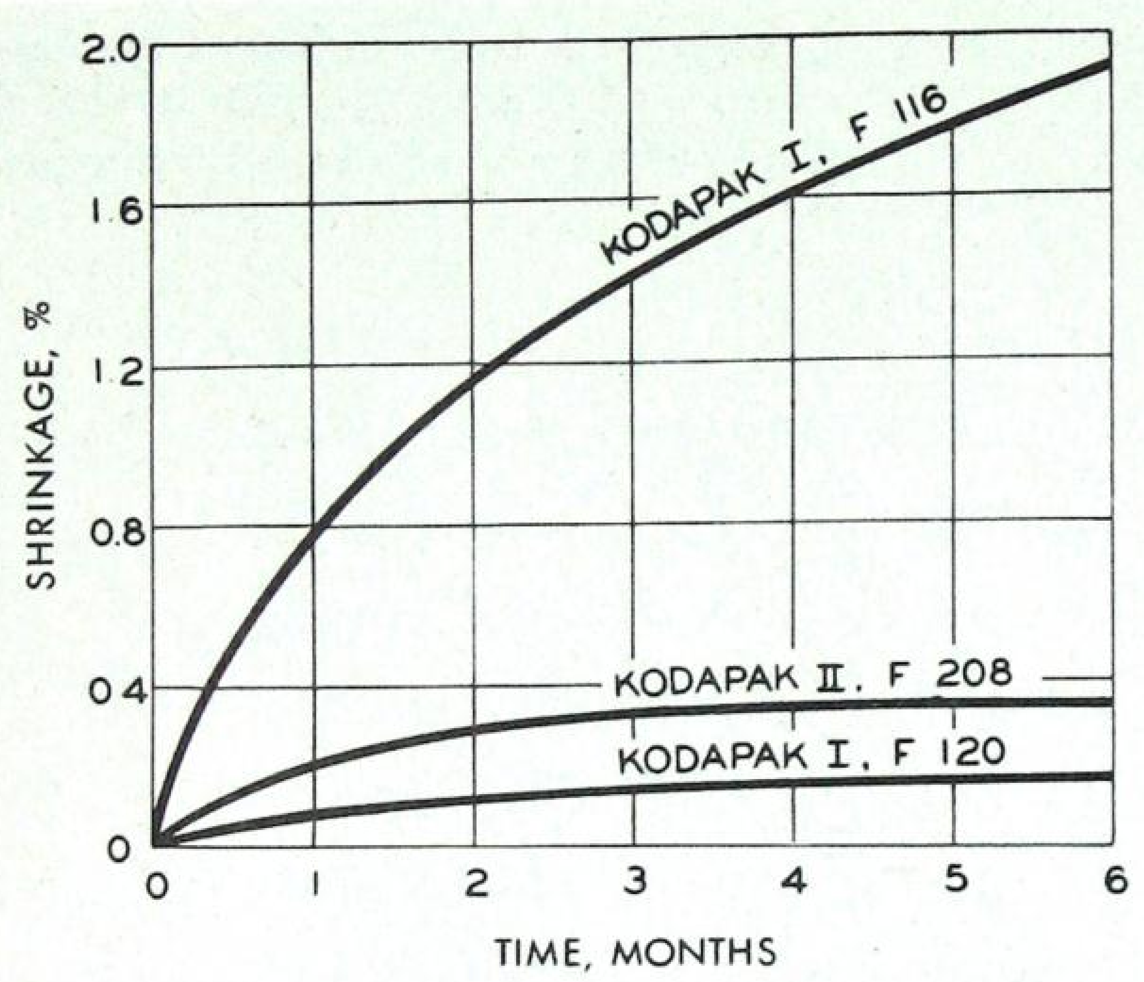


FIGURE 4—Approximate Rate of Shrinkage of 0.001″ Kodapak I Sheet and Kodapak II Sheet at 70° F., 50% R.H.

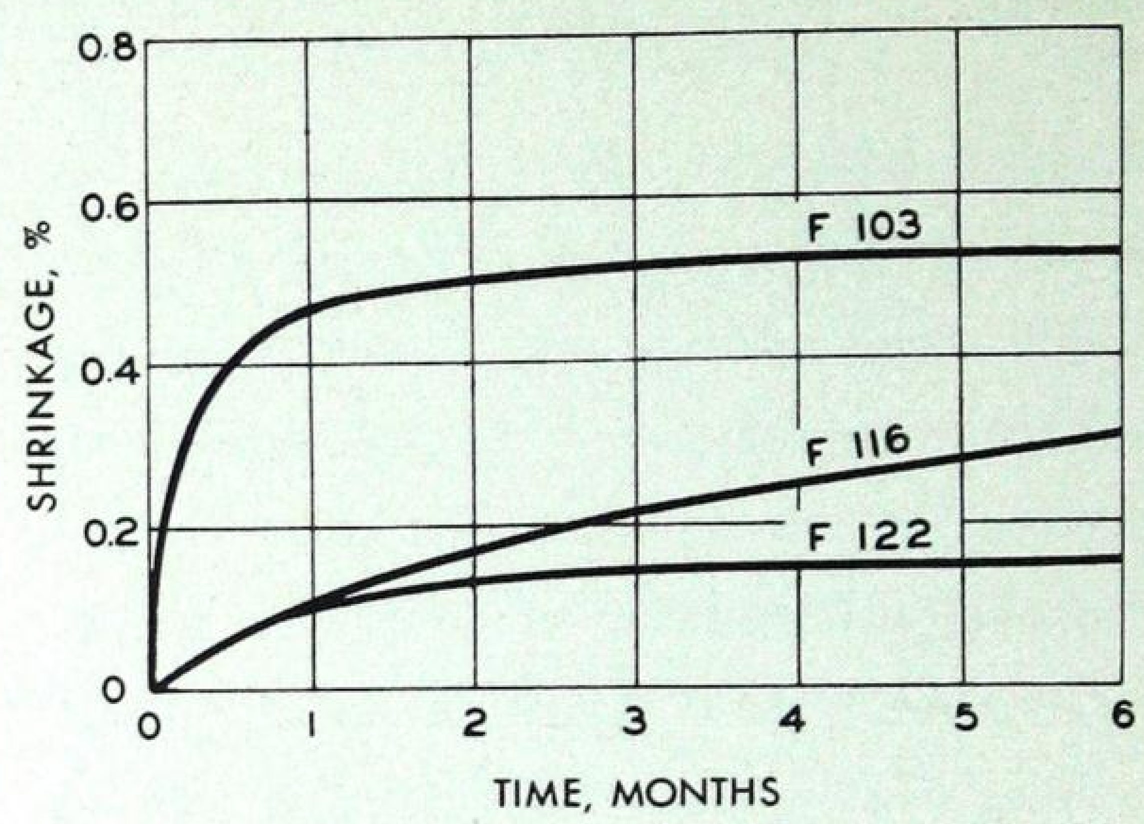


FIGURE 5—Approximate Rate of Shrinkage of 0.0075″ Kodapak I Sheet at 70° F., 50% R.H.

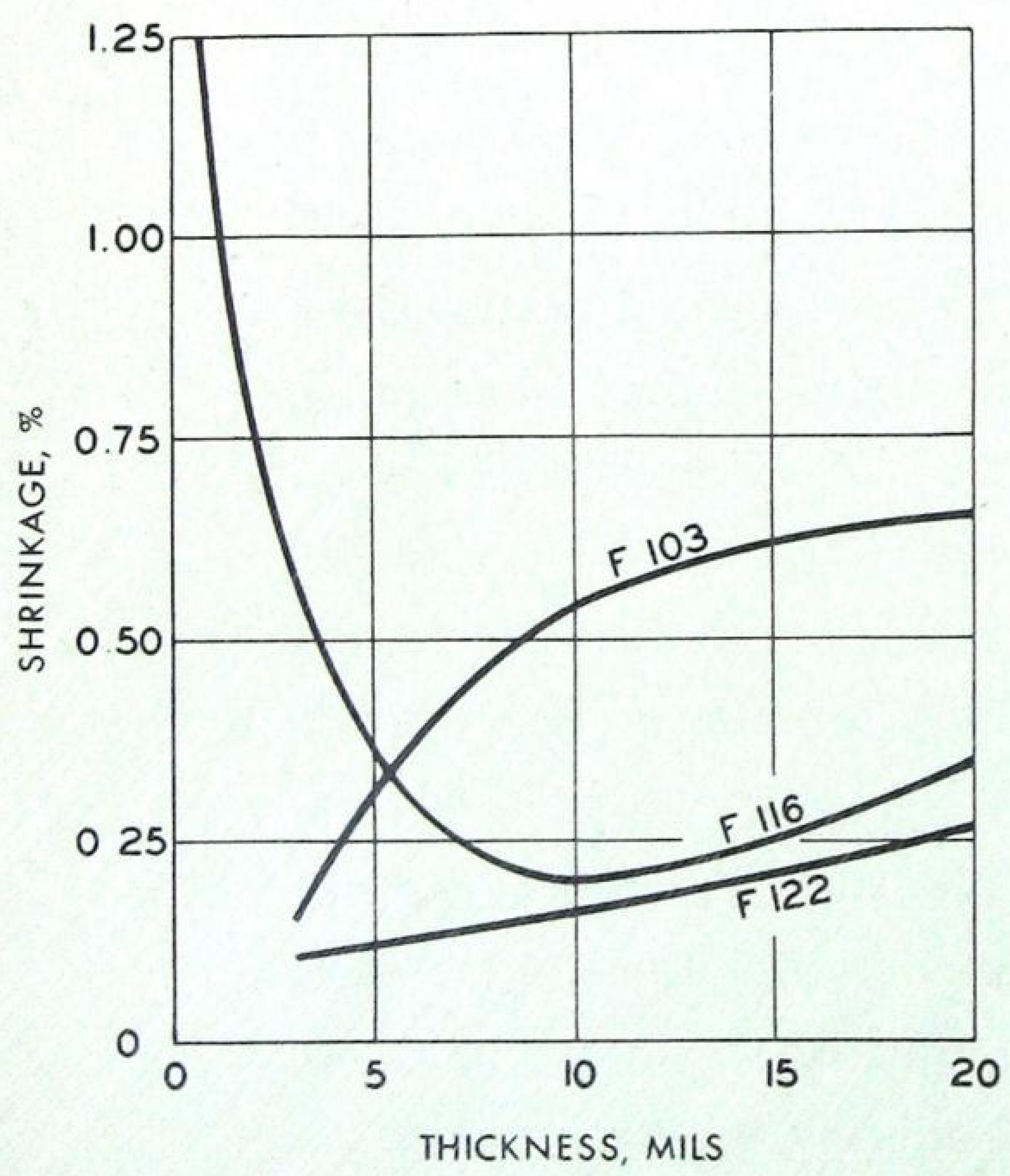


FIGURE 6—Effect of Thickness on the Shrinkage of Kodapak I Sheet in 3 Months at 70° F., 50% R.H.

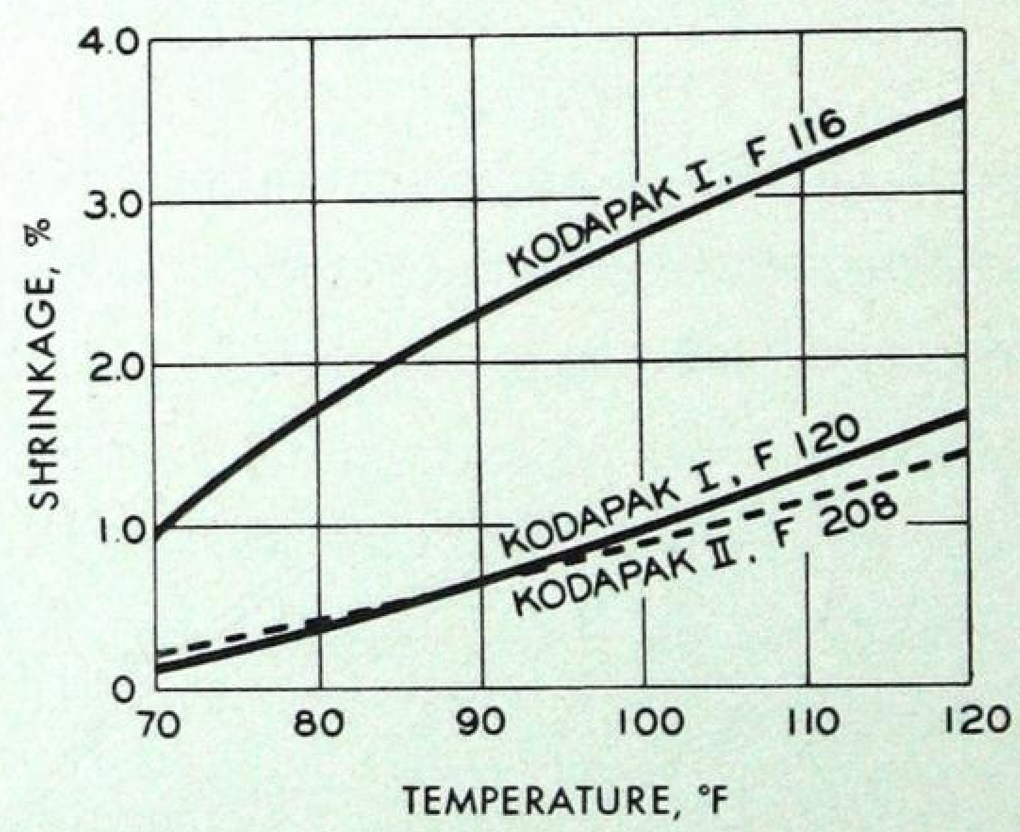


FIGURE 7—Effect of Temperature on the Shrinkage of 0.001″ Kodapak I Sheet and Kodapak II Sheet in 3 Months at 20% R.H.

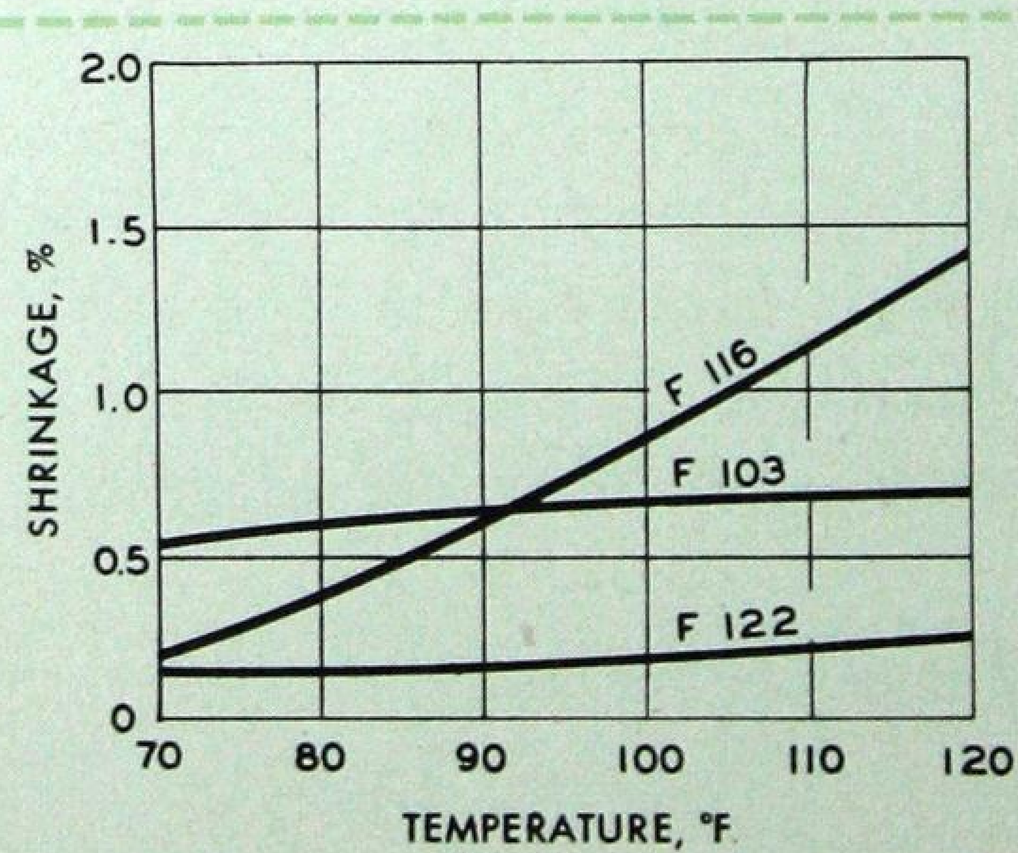
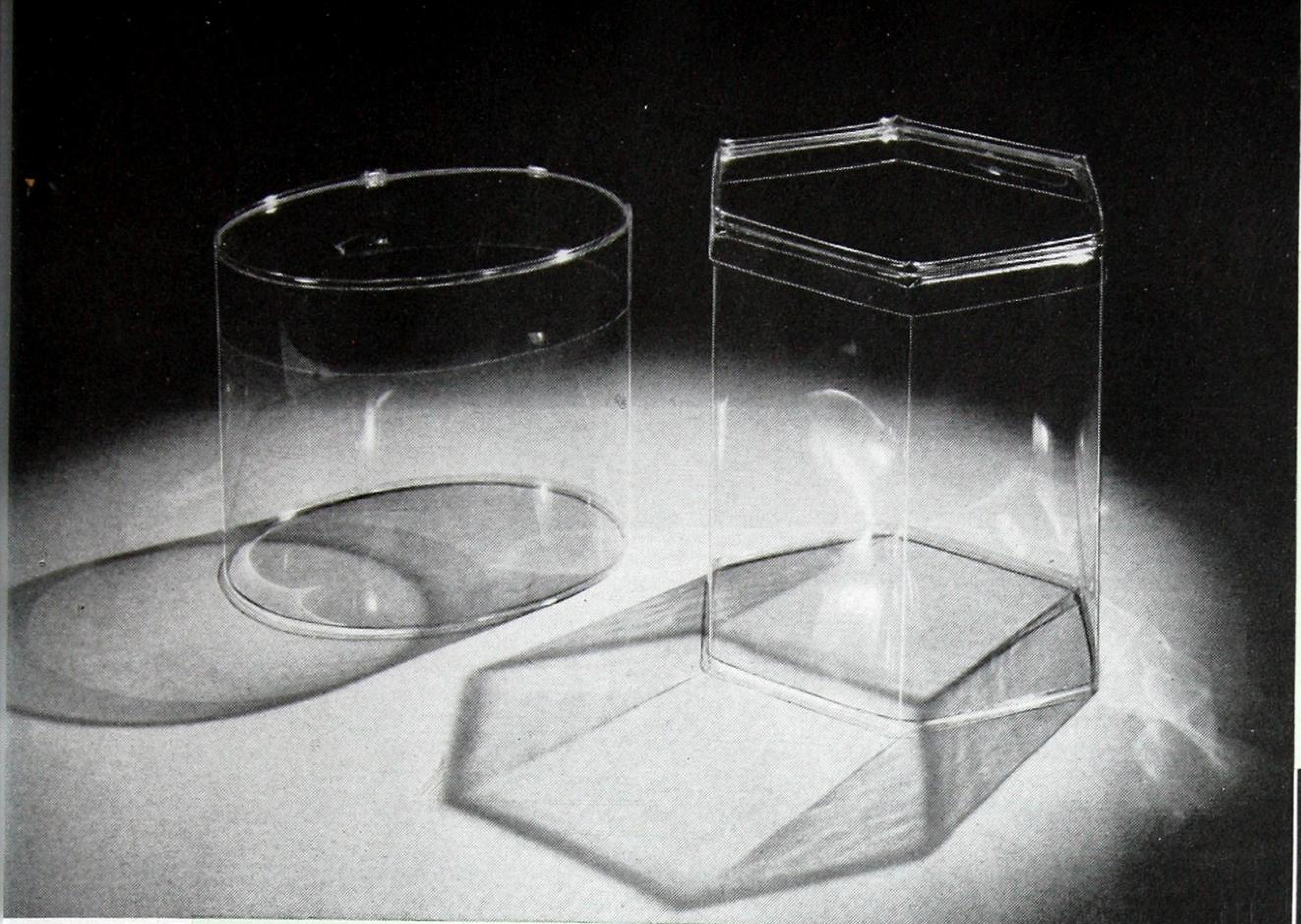


FIGURE 8—Effect of Temperature on the Shrinkage of 0.0075″ Kodapak I Sheet in 3 Months at 20% R.H.



As illustrated at the left, the rigidity of Kodapak I Sheet recommends it for set-up containers. It is also ideal for deep drawing.

Kodapak Sheet provides maximum protection and the brilliant display demanded in "high-fashion" applications.

MECHANICAL PROPERTIES

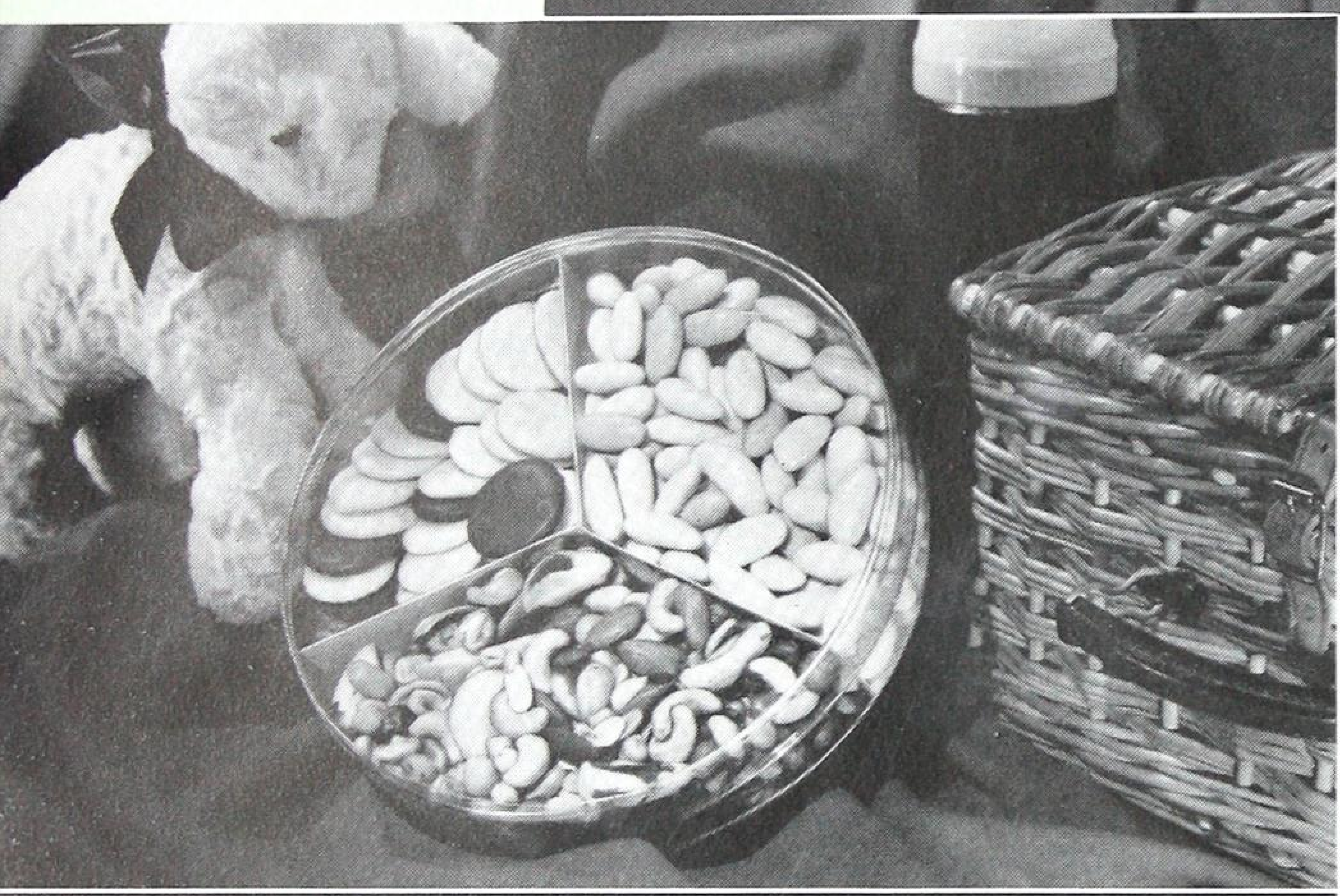
Among the more important mechanical properties of cellulose ester plastic sheets, in the gauge range of Kodapak Sheet, are tensile strength, elongation, toughness, stiffness, plastic flow, and tear resistance. The mechanical properties of Kodapak Sheet are summarized on pages 16 and 17.

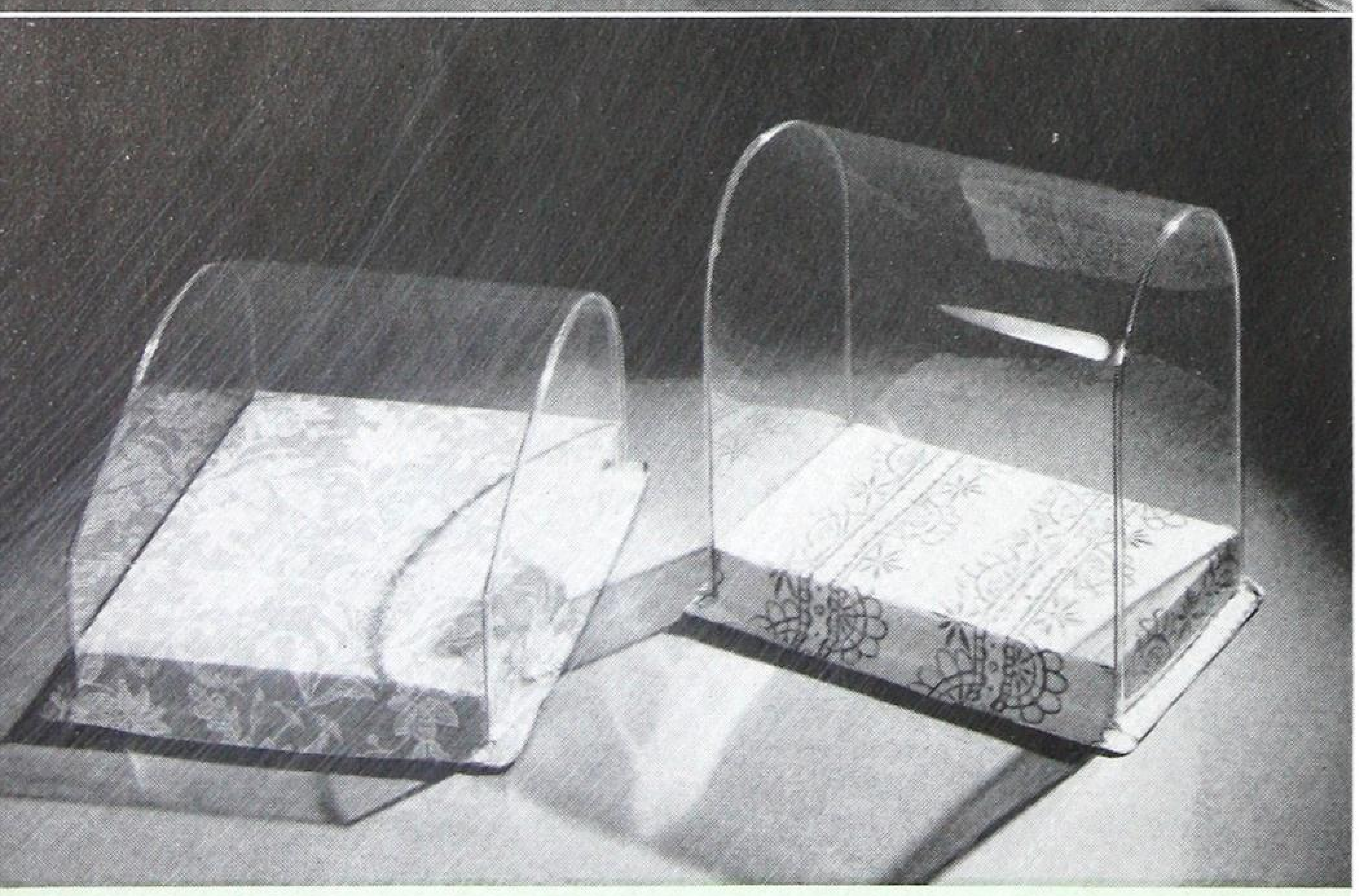
The tensile properties of a plastic material can be understood most readily with the aid of a stress-strain curve—that is, a plot of the tensile stress or load against the elongation of the sample when tested in a conventional tensile machine. Such stress-strain curves are shown for 0.002″ Kodapak Sheet in Figure 9, and for 0.0075″ Kodapak Sheet in Figure 10, page 9.

All Kodapak formulations are characterized by high tensile strengths which are of the same order

Large diameter circular or oval boxes are easily fabricated over special forms, custom made to fit the requirement.

Packaging novelty foods, candies, nuts, is a special province of Kodapak Sheet.





Kodapak Sheet for the transparent cover and specially decorated paper board for the opaque base make a happy combination.

of magnitude as those of such metals as aluminum and tin in the pure state. The rigid Kodapak I formulations, F103 and F120, have the highest tensile strength and the lowest elongation. Kodapak II Sheet, on the other hand, has the highest elongation. This latter fact is particularly important because of its relation to "energy-to-fracture" or toughness (pages 16 and 17) which is measured by the area under the stress-strain curve. The larger area under the stress-strain curve for Kodapak II (Figure 9) demonstrates the superior toughness of this material which recommends it so highly for electrical applications, foil lamination, certain packaging, and other uses.

Atmospheric conditions have an important influence on the tensile properties of plastics. In the case of cellulose ester sheets such as Kodapak, the tensile strength decreases and the elongation increases, with increase of both temperature and relative humidity. The elongation of Kodapak II remains appreciably higher than that of Kodapak I even at very low temperatures, which is important in electrical insulation applications. At 32°F., Kodapak II stretches about 35% and at −75°F. it stretches about 10% before breaking.

Stiffness, or modulus of elasticity, is another very important mechanical property of a plastic sheet. The rigidity of a transparent container, the stiffness of a transparent envelope, etc., all depend on the modulus of elasticity of the material and the thickness of the sheet selected. The modulus of elasticity of each Kodapak formulation is given in the table, pages 16 and 17. The rigid Kodapak I formulations (F103 and F120) have the highest modulus and, therefore, are recommended for applications where rigidity is desired. It should be noted that the modulus of elasticity of cellulose ester plastics decreases with increase in temperature and increase in relative humidity.

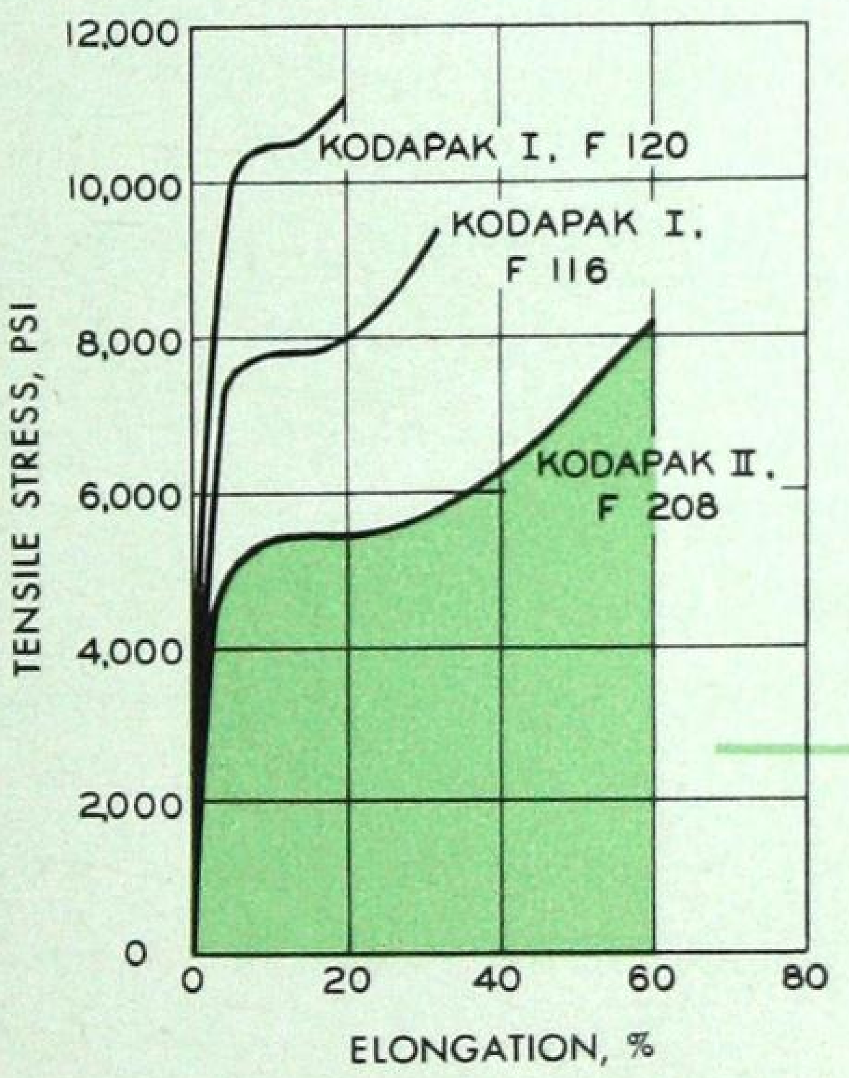
When selecting the gauge of sheet for a particular end use, it must be remembered that the apparent stiffness in flexure is proportional to:

$$E \times \frac{WD^3}{L}$$

where E = modulus of elasticity in flexure, W = width, D = thickness, L = length.

Since the thickness is cubed, it has relatively a much greater effect than modulus of elasticity on the apparent stiffness of a sheet. This is illustrated in Figure 11 which shows, for example, that a 100% increase in modulus of elasticity would only permit a 20% reduction in sheet thickness, if the apparent stiffness were to remain the same. Consequently, .0075″ Kodapak I Sheet, F103, for example, although definitely stiffer than the same thickness of F116, should not be expected to be as rigid as .010″ F116.

Plastic flow is a phenomenon characteristic of plastic materials which is of considerable practical importance to the user. When a plastic material is subjected to a stress or load in either tension, compression, flexure, or torsion over a period of time, the initial elastic deformation gradually increases and plastic flow (sometimes called cold flow) is said to occur. When the load is removed, the material does not return completely to its original shape or



The superior toughness of Kodapak II Sheet is indicated by the relatively large area beneath its stress-strain curve.

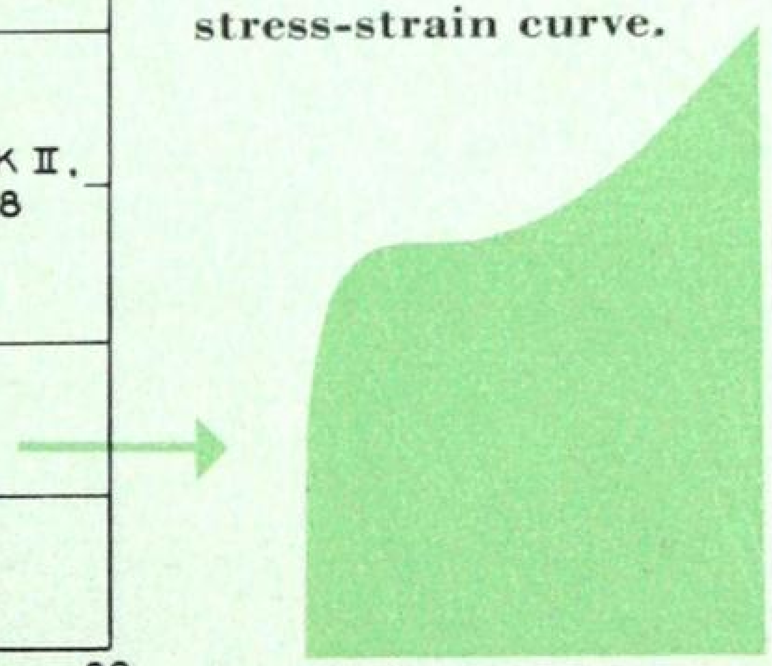


FIGURE 9 — Stress-Strain Curves for 0.002″ Kodapak I Sheet and Kodapak II Sheet at 70° F., 50% Relative Humidity.

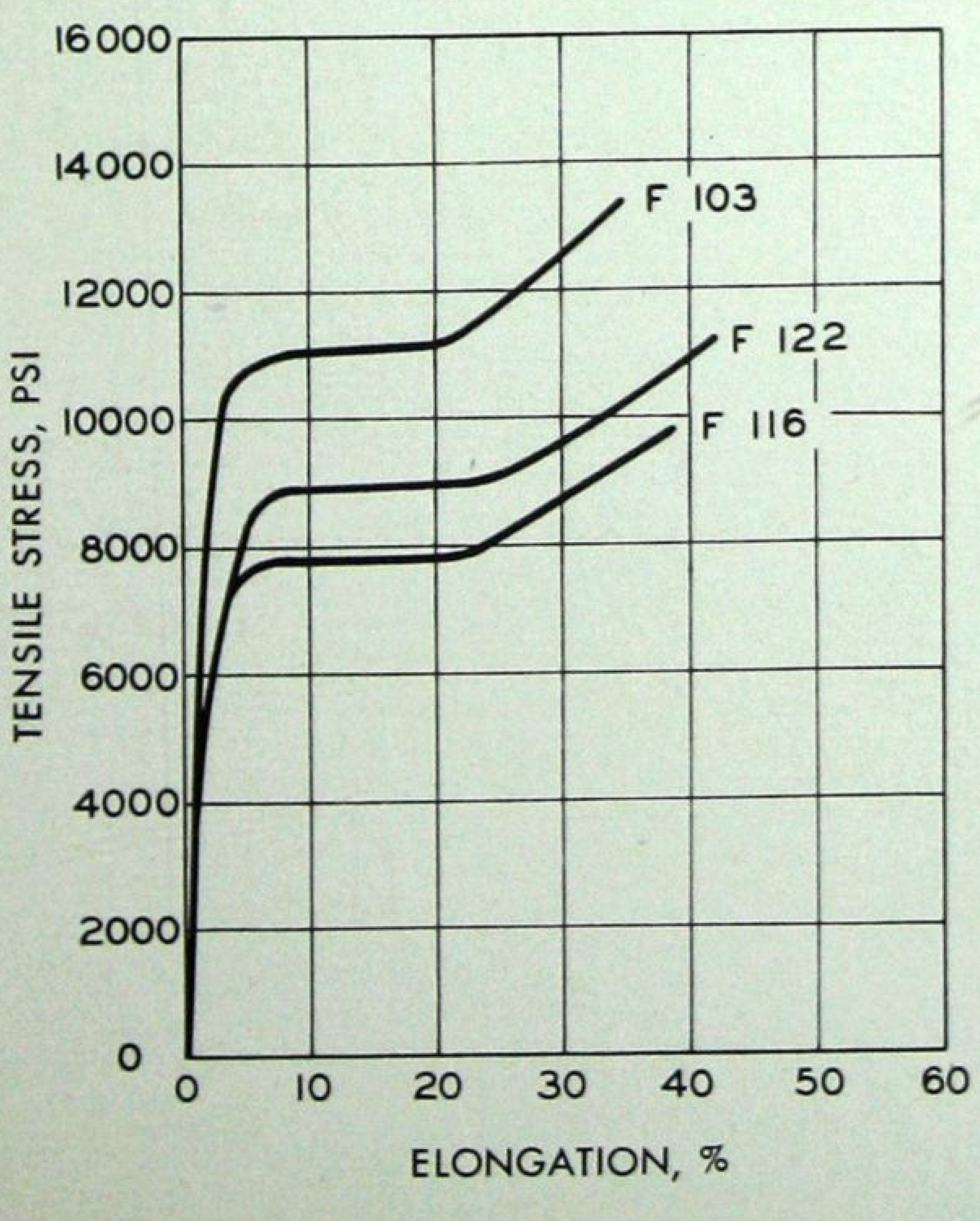


FIGURE 10 — Stress-Strain Curves for 0.0075″ Kodapak I Sheet at 70° F., 50% Relative Humidity.

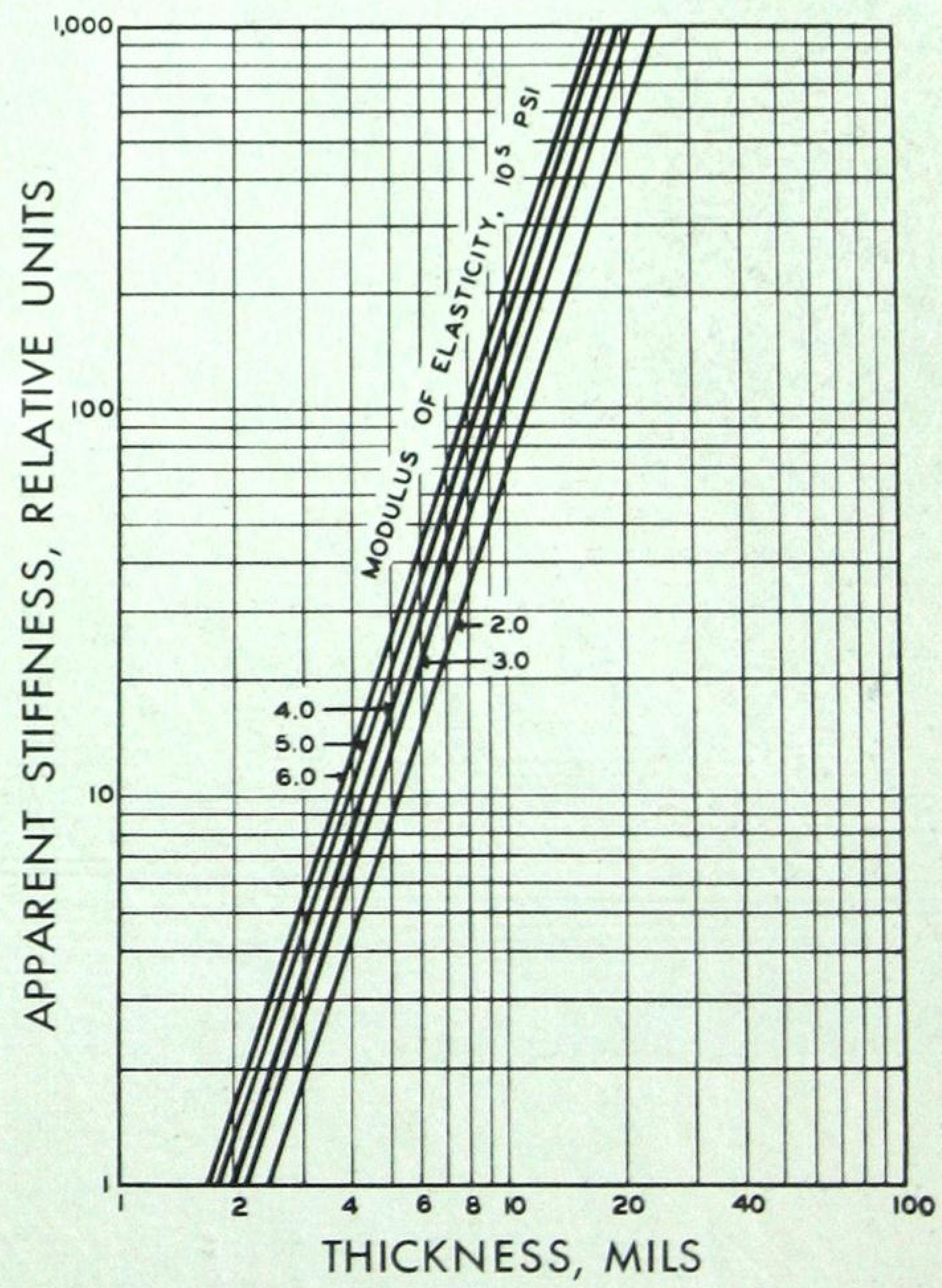


FIGURE 11 — Theoretical Relation between Apparent Stiffness, Modulus of Elasticity in Flexure, and Thickness for Sheet Materials.

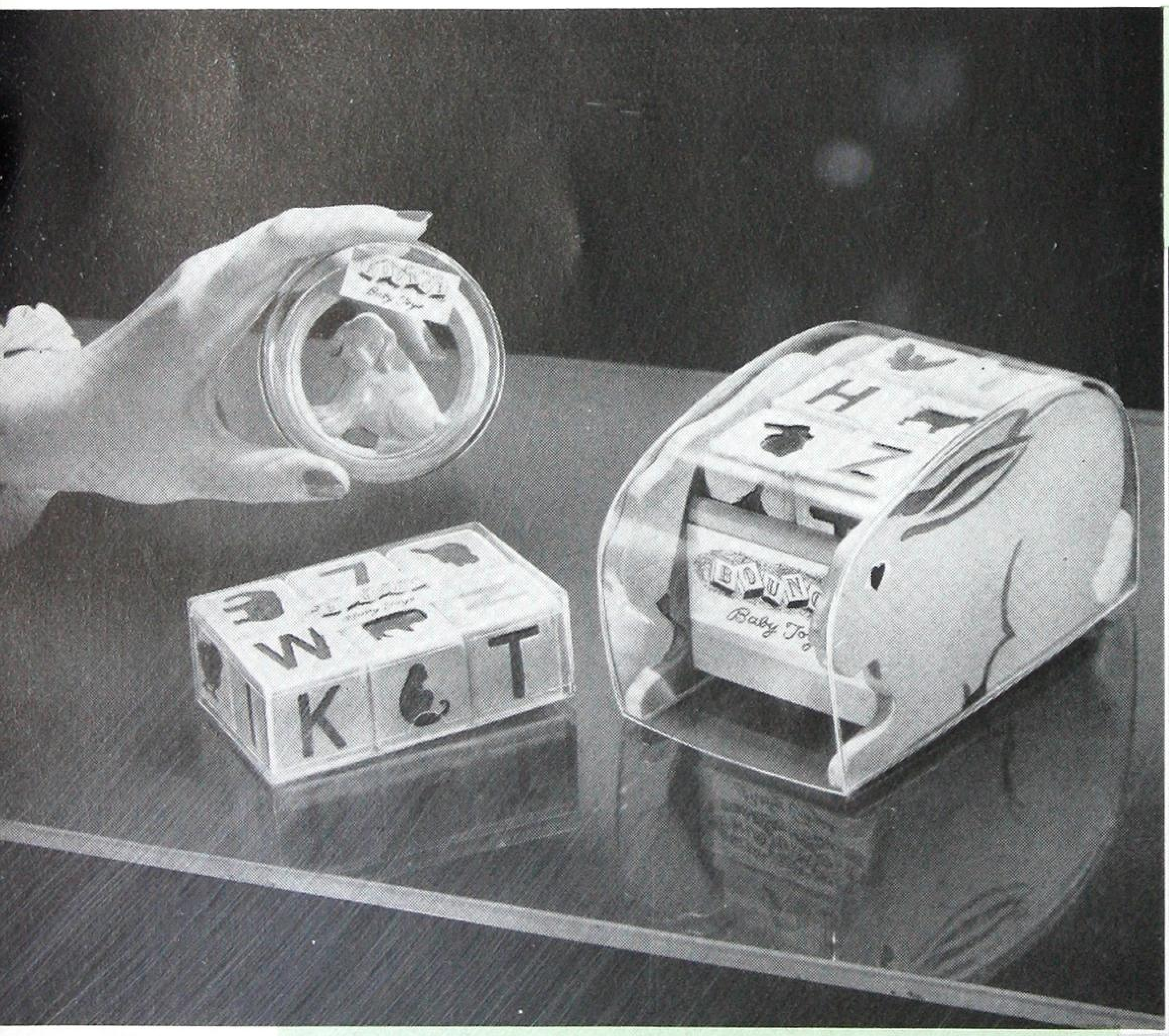
dimensions and the residual deformation is described as "permanent set." The plastic flow or permanent set which occurs increases with the magnitude and duration of the applied load, the temperature, and the moisture content of the material.

Easily Drawn or Formed

In practice, this means that Kodapak Sheet or similar plastics will be permanently deformed if subjected to sufficient stress under certain conditions of time and temperature. One very desirable consequence of this behavior is that Kodapak Sheet may be easily drawn or formed to any particular shape by the application of heat and pressure.

An undesirable result of plastic flow is the permanent set which occurs when plastic sheets are allowed to stand for a long time in roll form. When unwound, the sheet, instead of lying flat, tends to retain the shape of the roll. This type of permanent set increases with decrease in roll diameter and increase in sheet thickness. It is for this reason that the heavier gauges, particularly 0.020″, are usually sold in sheets in preference to rolls. When curvature caused by storage in roll form is encountered, it can be eliminated or minimized by rewinding the roll inside out, and allowing it to stand for several days before use.

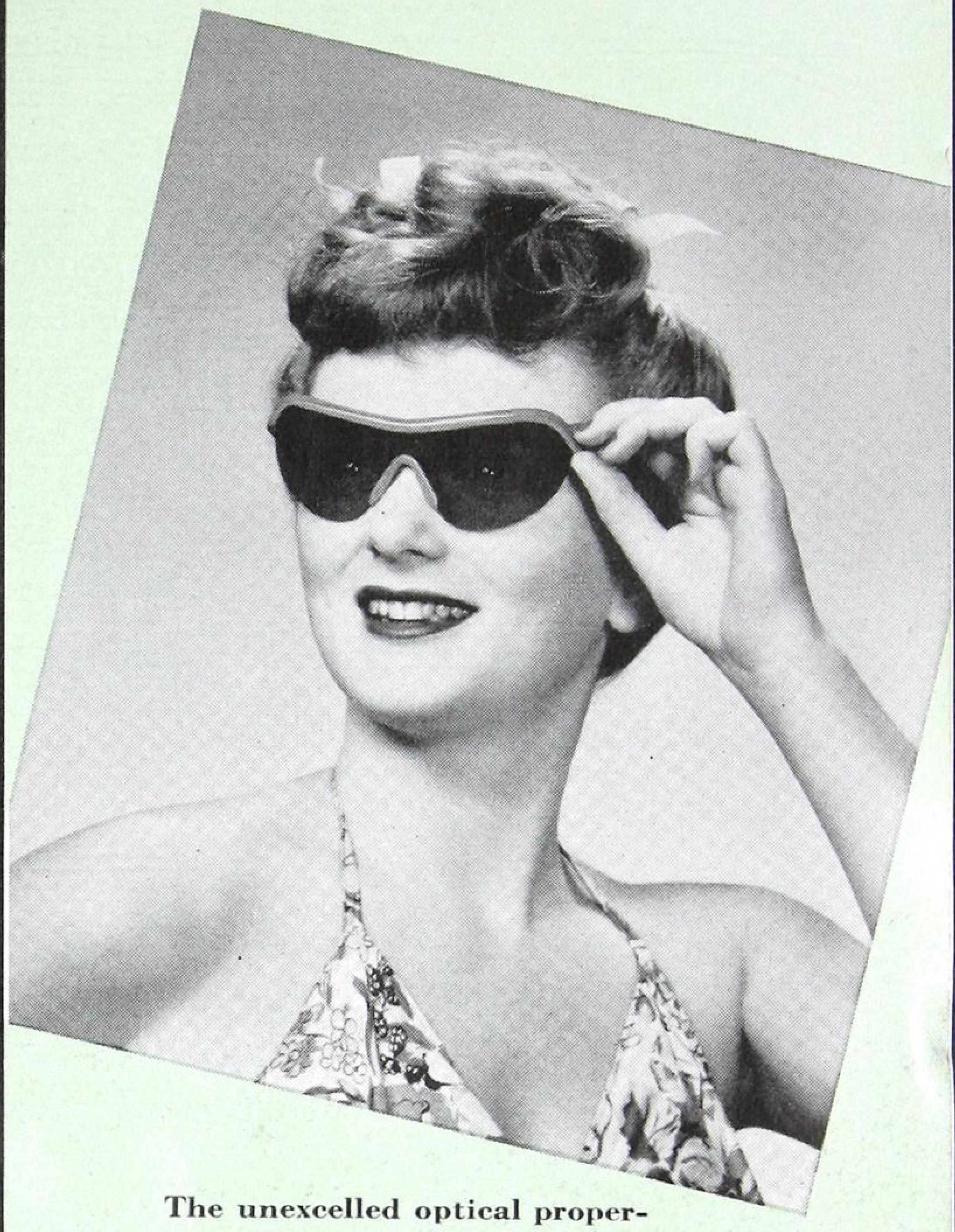
Tear resistance is a necessary characteristic of a plastic sheet. Values for the tear resistance of Kodapak Sheet are listed on pages 16 and 17. The tear resistance increases with the thickness of the material so that the values listed for 0.001″ gauge are small. Unlike tensile strength and stiffness, the tear resistance increases as the temperature and relative humidity increase.



Kodapak's high transparency helps to "trade-up" these toys.

Optical clarity and freedom from distortion make Kodapak Sheet desirable for face shields and goggles.

Kodapak II Sheet, cellulose acetate butyrate, laminated with cotton scrim, is long lasting, weather resistant, and transmits a wide range of ultraviolet radiation.



The unexcelled optical properties of Kodapak Sheet contribute to the success of the Polaroid goggle.

OPTICAL PROPERTIES

Since Kodapak Sheet is manufactured under the same rigid conditions as Kodak photographic film base, it is exceptionally free from haze, dirt, and minute optical defects. It is for this reason that Kodapak Sheet is unexcelled among cellulose ester plastic sheets in optical clarity and surface brilliance. These characteristics make Kodapak Sheet particularly desirable for such optical uses as visors, face guards, sun glasses, radio dial covers, equipment windows, etc., as well as for transparent containers where its brilliance adds greatly to display value.

Data for the refractive index and white light transmission of Kodapak Sheet are given on pages 16 and 17. Spectrophotometric transmission curves are shown for 0.001″ Kodapak I (in the ultraviolet region) in Figure 12, page 12, and for 0.0075″ Kodapak in Figure 13. The "cut-off" is below 300 millimicrons which means that a considerable portion of the ultraviolet radiation (below 400 millimicrons) is transmitted. For this reason, Kodapak Sheet is superior to glass for use in solariums, poultry runs, and greenhouses. When strengthened by lamination with coarse-mesh cotton scrim, thin-gauge Kodapak II Sheet produces

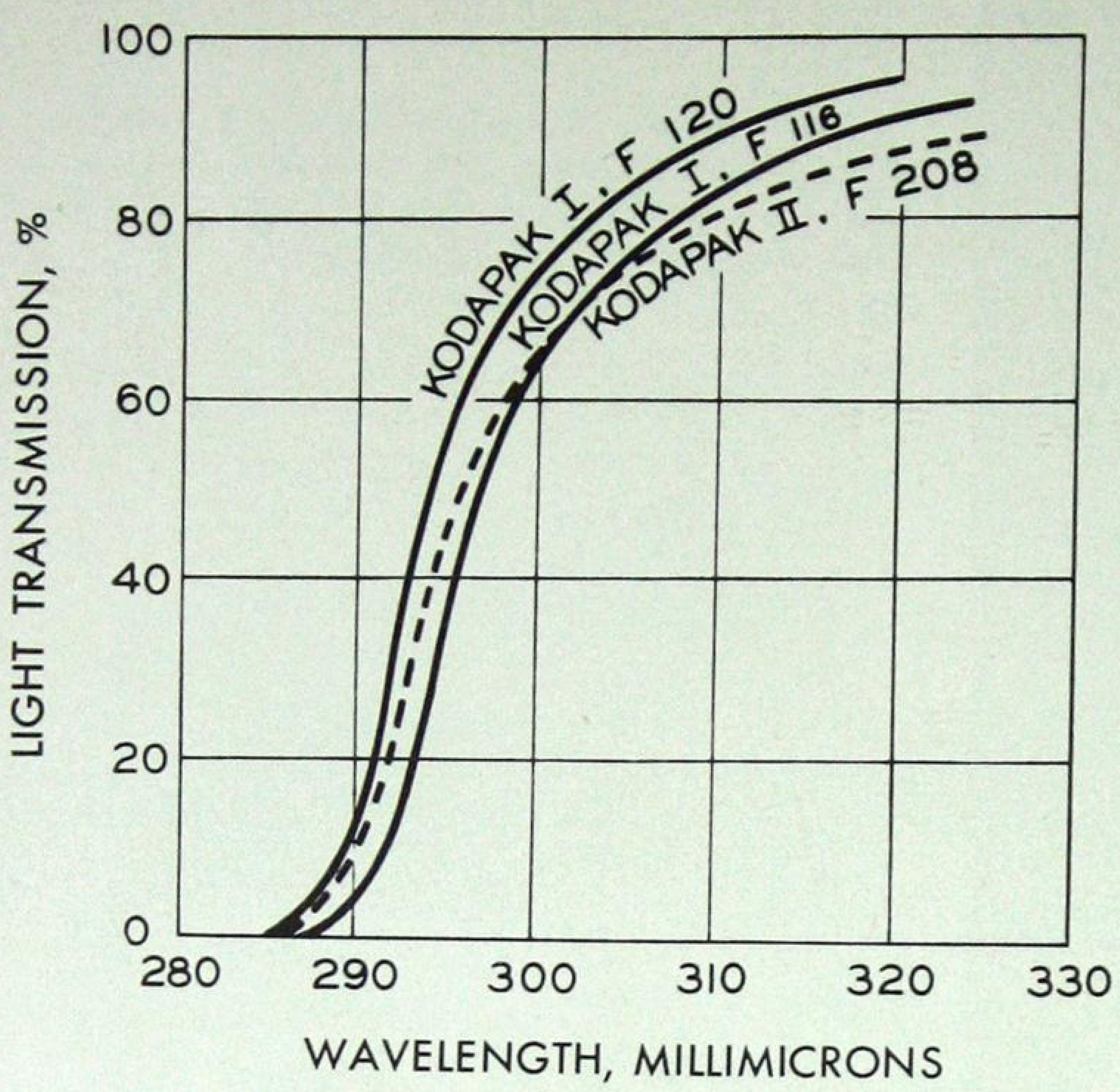


FIGURE 12 — Spectrophotometric Transmission Curves for 0.001″ Kodapak I Sheet and Kodapak II Sheet in the Ultraviolet Range.

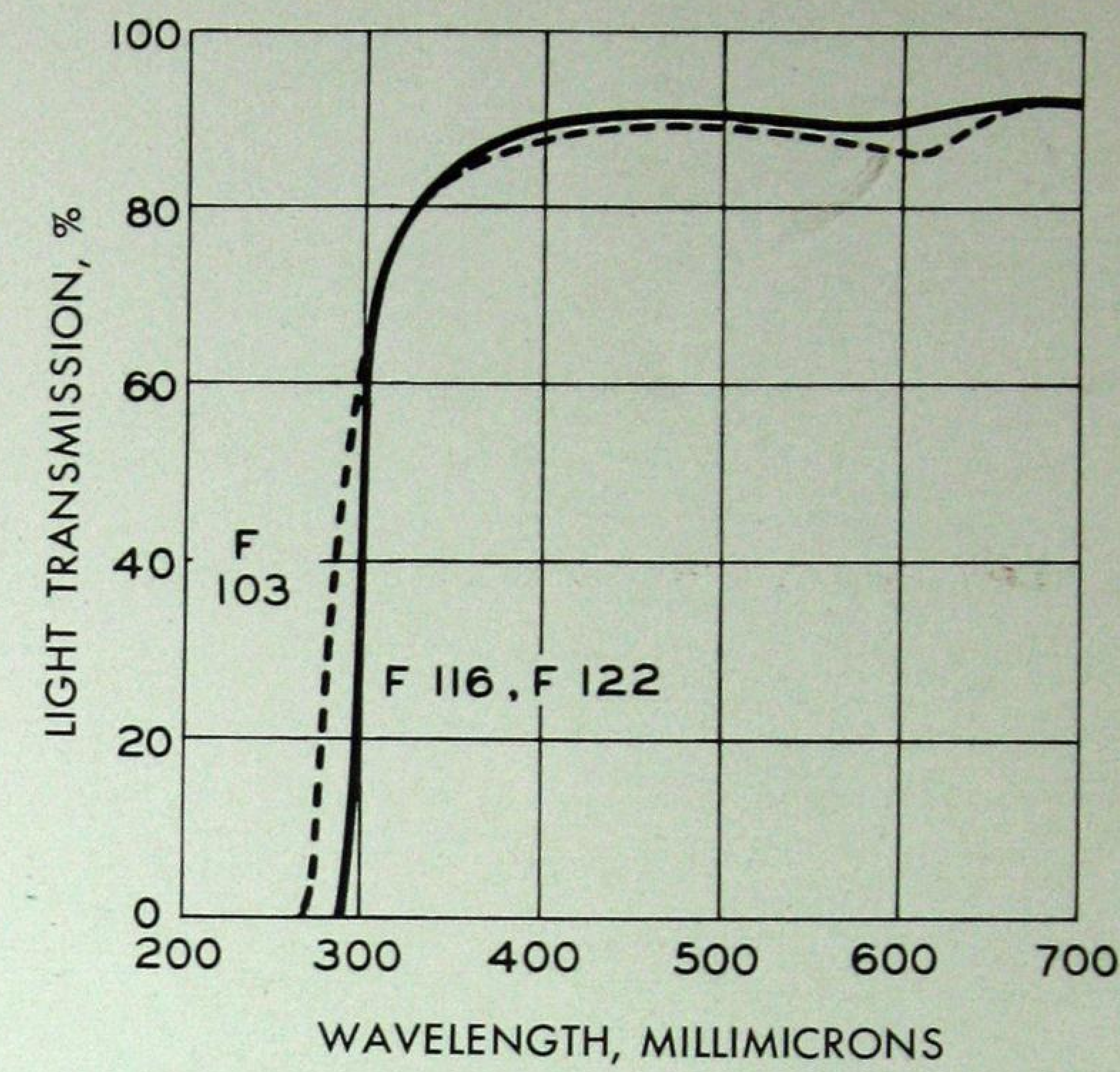


FIGURE 13 — Spectrophotometric Transmission Curves for 0.0075″ Kodapak I Sheet in the Ultraviolet and Visible Range.

a light-weight, long-lasting, weather-resistant type of material which transmits a wide range of the sun's health-giving ultraviolet rays. Kodapak Sheet can thus be used to advantage in hospitals, in homes and offices, and on farms. Such a window screen is illustrated on page 11.

THERMAL PROPERTIES

The thermal properties of Kodapak Sheet are summarized on pages 16 and 17. The flammability tests show that Kodapak formulations F103, F122, and F124 are self-extinguishing, while the remainder burn very slowly. Self-extinguishing means that although the material will burn when held in a flame from some other source, it stops burning when the flame is removed. In the case of the slow-burning materials such as F116, the burning rate decreases as the thickness increases, as illustrated in Figure 14. In the light gauges, Kodapak II Sheet has a lower burning rate than Kodapak I. However, all Kodapak formulations offer no more hazard in use than ordinary newsprint, an important practical consideration.

Values for the thermal coefficient of linear expansion of Kodapak Sheet are given on pages 16 and 17. The thermal expansion of Kodapak I per °F. is considerably lower than the humidity expansion per 1% relative humidity so that the latter factor is usually the more important.

In the case of Kodapak II Sheet, the thermal expansion per °F. is of the same order of magnitude as the humidity expansion per 1% of relative humidity.

The penetration temperatures and heat distortion temperatures of Kodapak Sheet, listed on pages 16 and 17, are arbitrary measurements to indicate the relative heat resistance of the different formulations.* The values given cannot be translated directly into practical terms, although the heat distortion temperature does correlate with the recommended forming temperature. These tests indicate that Kodapak I Sheet has a higher heat resistance than Kodapak II and that formulations F103 and F120 have higher heat resistance than F116.

*See page 19 for a brief description of the test methods.

The forming temperatures given on pages 16 and 17 are equipment temperatures and not sheet temperatures. This is an important distinction, for while in high-speed equipment the indicated operating temperature may even exceed the sticking point, the Kodapak sheet never actually reaches this temperature. The optimum forming temperatures depend so much on other conditions such as pressure, time, gauge, etc., that the values given on pages 16 and 17 should be used only as a guide. More detailed information on forming is given in our booklet, "Fabrication of Kodapak Sheet."

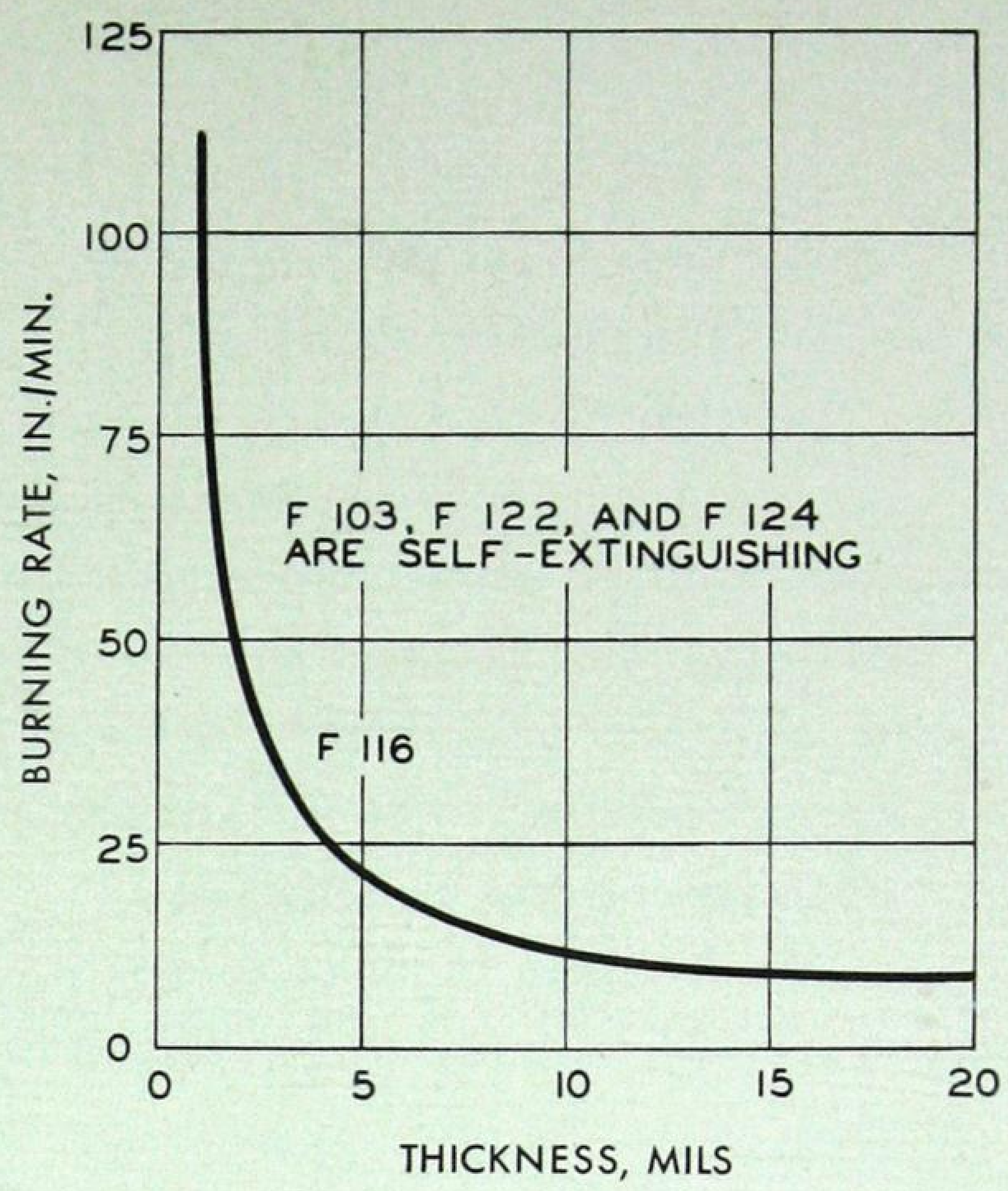


FIGURE 14—Effect of Thickness on the Burning Rate of Kodapak I Sheet, F116.

CHEMICAL PROPERTIES

In regard to chemical properties, cellulose organic-acid esters are relatively stable to most reagents but are attacked by strong alkalis and strong acids. Except for contact with such chemicals or certain organic solvents, Kodapak Sheet is an extremely stable and permanent material.

The effect of various solvents on Kodapak Sheet is summarized on pages 16 and 17. Where figures are given for A.S.T.M. D543-43, a weight gain of less than 5% is considered negligible. In general, Kodapak I Sheet (cellulose acetate) is soluble in the lower ketones and aliphatic esters, for example, acetone and ethyl acetate respectively. It is softened only slightly by alcohols, and is unaffected by hydrocarbons.

Kodapak II Sheet (cellulose acetate butyrate) is soluble in the lower ketones and esters, and some chlorinated hydrocarbons, such as ethylene dichloride. It swells in some alcohols and aromatic hydrocarbons, such as toluene. Both Kodapak I and Kodapak II may be easily and quickly cemented by means of suitable solvent mixtures. Prepared cements are available for this purpose.

ELECTRICAL PROPERTIES

The electrical properties of Kodapak Sheet are summarized on pages 16 and 17. Under normal conditions, Kodapak I and Kodapak II have very nearly the same dielectric strength, dielectric constant and power factor. However, Kodapak II Sheet is particularly recommended for certain electrical applications because of its superior moisture resistance and greater stretch and toughness.

Kodapak Sheet is well suited for use as electrical insulation because of its high dielectric strength, particularly in low or medium frequency applications. The chemical stability of Kodapak Sheet and its high degree of purity insure freedom from corrosion failure. The fact that Kodapak Sheet is slow-burning is also an important consideration in electrical insulation problems.

The *dielectric strength* of Kodapak Sheet of various gauges is given in Figure 15. In a thickness of 0.0016″, for example, Kodapak Sheet has a breakdown strength of 3300 volts per mil or a total breakdown strength of about 5300 volts. Therefore, wire wound with Kodapak II tape in a 50% to 60% overlap has adequate primary insulation for a great variety of applications. Kodapak Sheet retains its dielectric strength over a wide range of temperatures. At −50°F., the breakdown strength is somewhat higher than that shown in Figure 15, and at 200°F., it is approximately 10% lower. The effect of

temperature on the insulation resistance of Kodapak Sheet is illustrated in Figure 16.

The ability of Kodapak II Sheet to stretch about 60% of its length before breaking (see page 9) enables it to be wound around wire by high speed machines. This property also allows a wire insulated with Kodapak II to be flexed or bent sharply around small radii without harming the insulation.

Primary Wire Insulation

Where Kodapak II Sheet is used for primary wire insulation, a protective overcoating of cotton, glass, or rayon braid is generally employed. The whole is then lacquered and the lacquer solvents tend to seal the tape to form a continuous waterproof tube around the wire. This treatment protects the wire from corrosion and mechanical damage as well as providing the necessary electrical insulation.

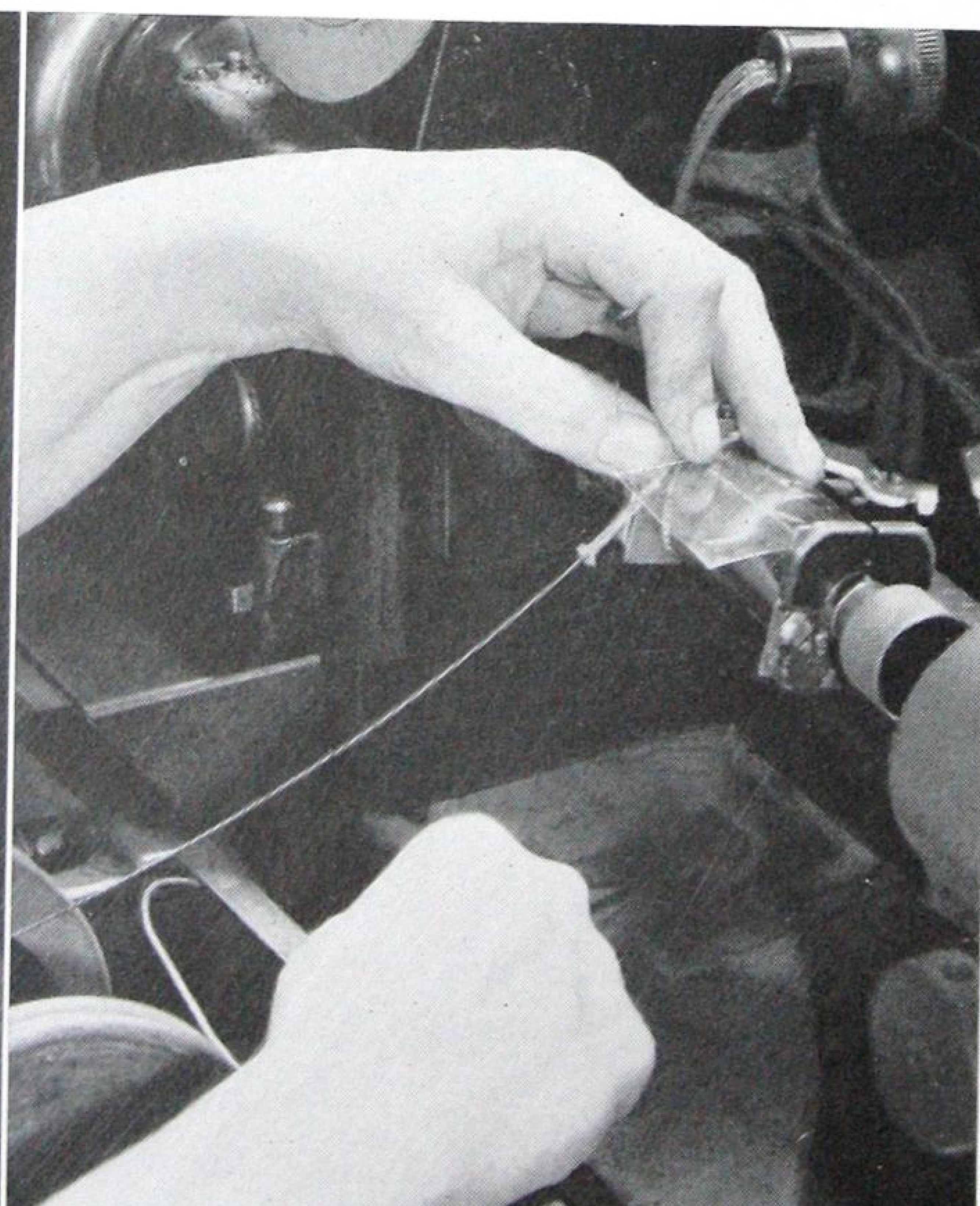
Wire wound with Kodapak tape as a primary insulation is always perfectly centered, which is not always the case when the insulation is extruded. This enables the overall diameter to be kept at a minimum.

In addition to use in wire insulation, Kodapak II Sheet is an ideal material for applications such as interlayer insulation in telephone relays and transformer coils, etc., where high dielectric strength and low insulation thickness are decisive factors.

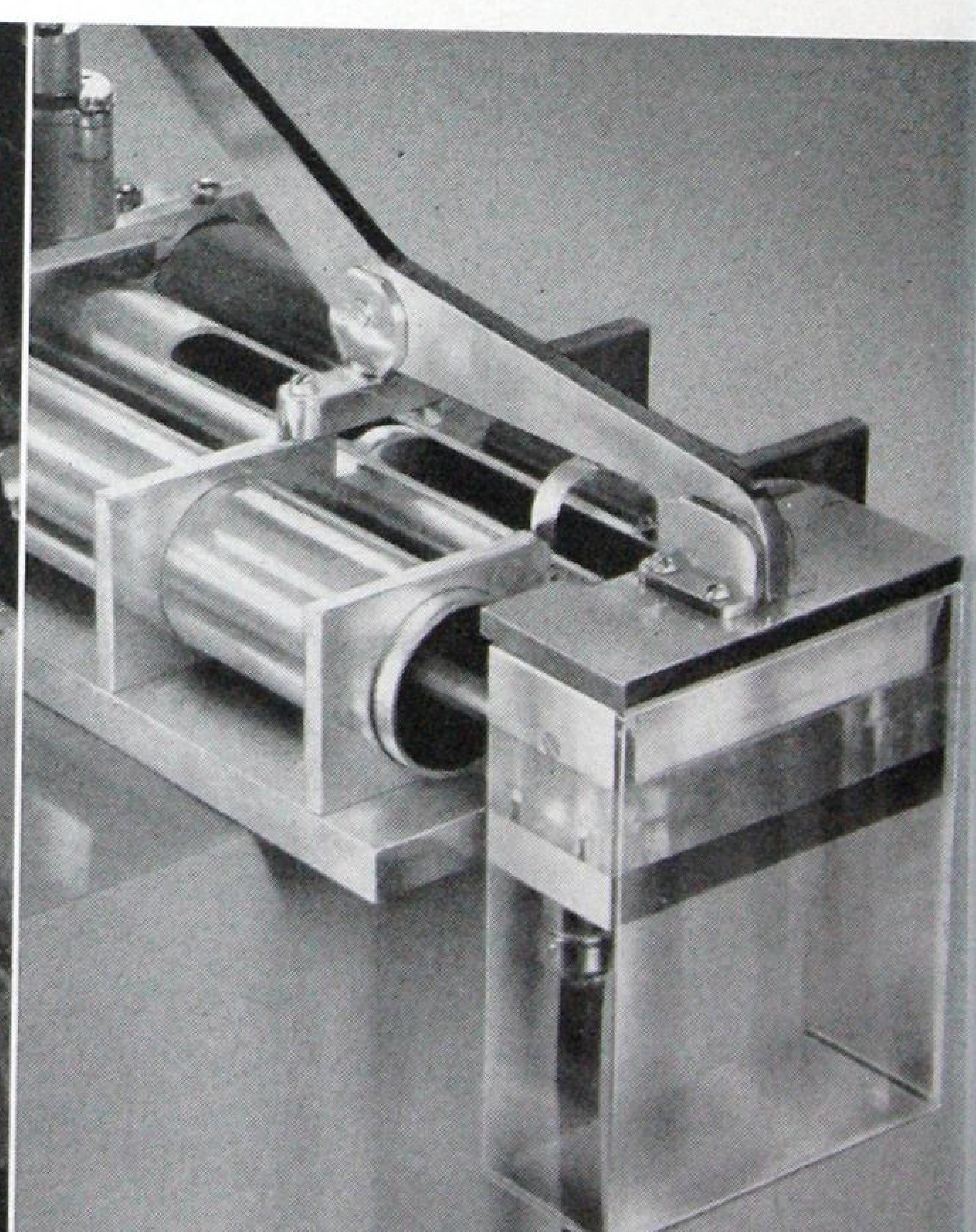
A Condenser Dielectric

Kodapak Sheet is also recommended for use as the dielectric in condensers. The dielectric constant of Kodapak Sheet is high enough to permit a condenser of small dimensions to be made without the use of impregnants. This is especially true if foil electrodes are applied by vacuum deposition of metal directly on the Kodapak Sheet. This technique reduces the number of intervening air films. In condenser applications, it is desirable that the power factor of the dielectric material be low. Figure 17, page 15, shows how the dielectric constant and power factor of Kodapak Sheet vary with relative humidity. The power factor of Kodapak II increases to a much smaller extent at high humidities than that of Kodapak I because of the superior moisture resistance of Kodapak II. A condenser made of Kodapak II Sheet can also be exposed to high relative humidities for extended periods of time without failure, because of the low moisture absorption of the material.

Primary wire insulation in cable construction. Winding with Kodapak Sheet permits smaller diameters with the assurance of maximum protection.



Kodapak Sheet's dielectric properties, its compactness and light weight, recommend it for interleaving the windings in coil manufacture.



High-frequency heat sealing of setup boxes and other seams is a growing fabrication method, providing a narrow, accurate overlap.

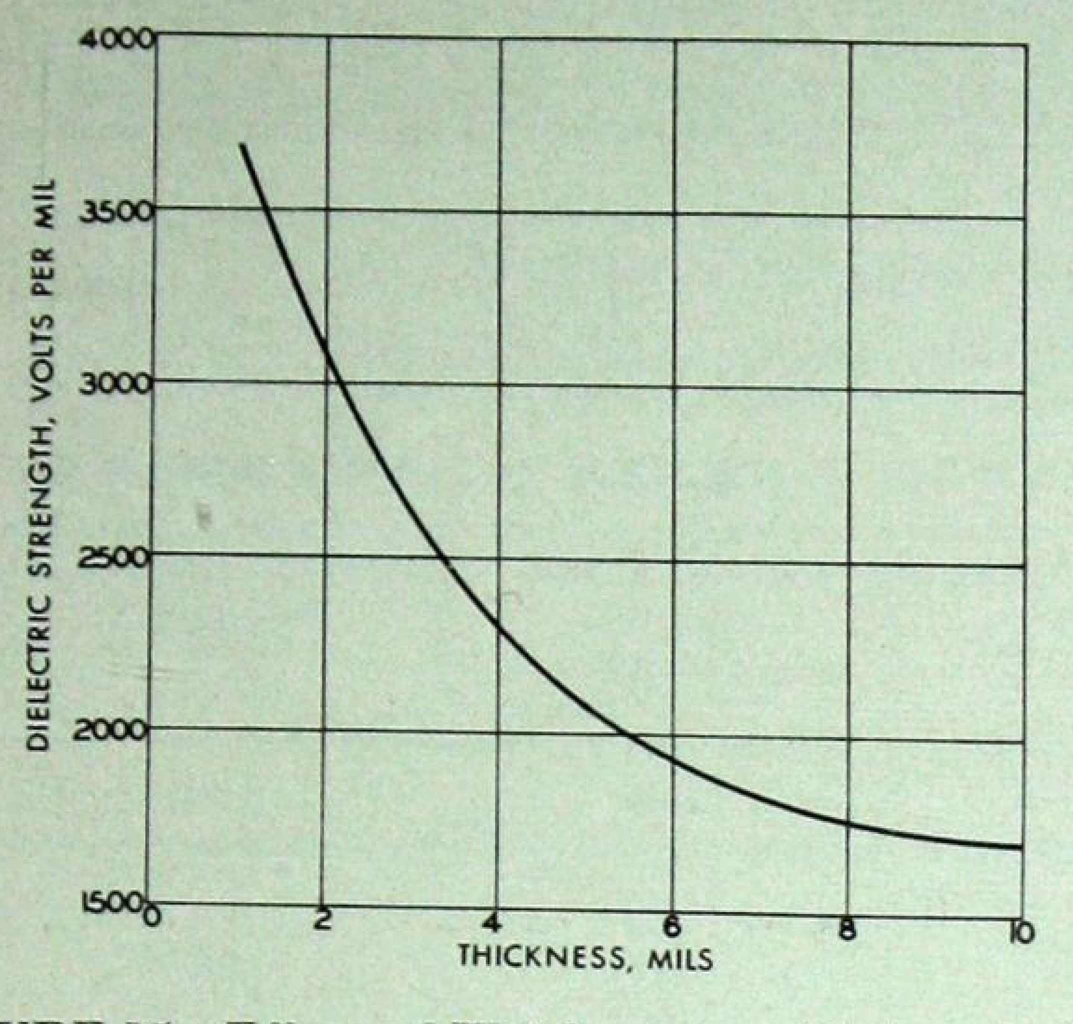


FIGURE 15—Effect of Thickness on Dielectric Strength of Kodapak Sheet at approximately 75° F., 30% R.H.

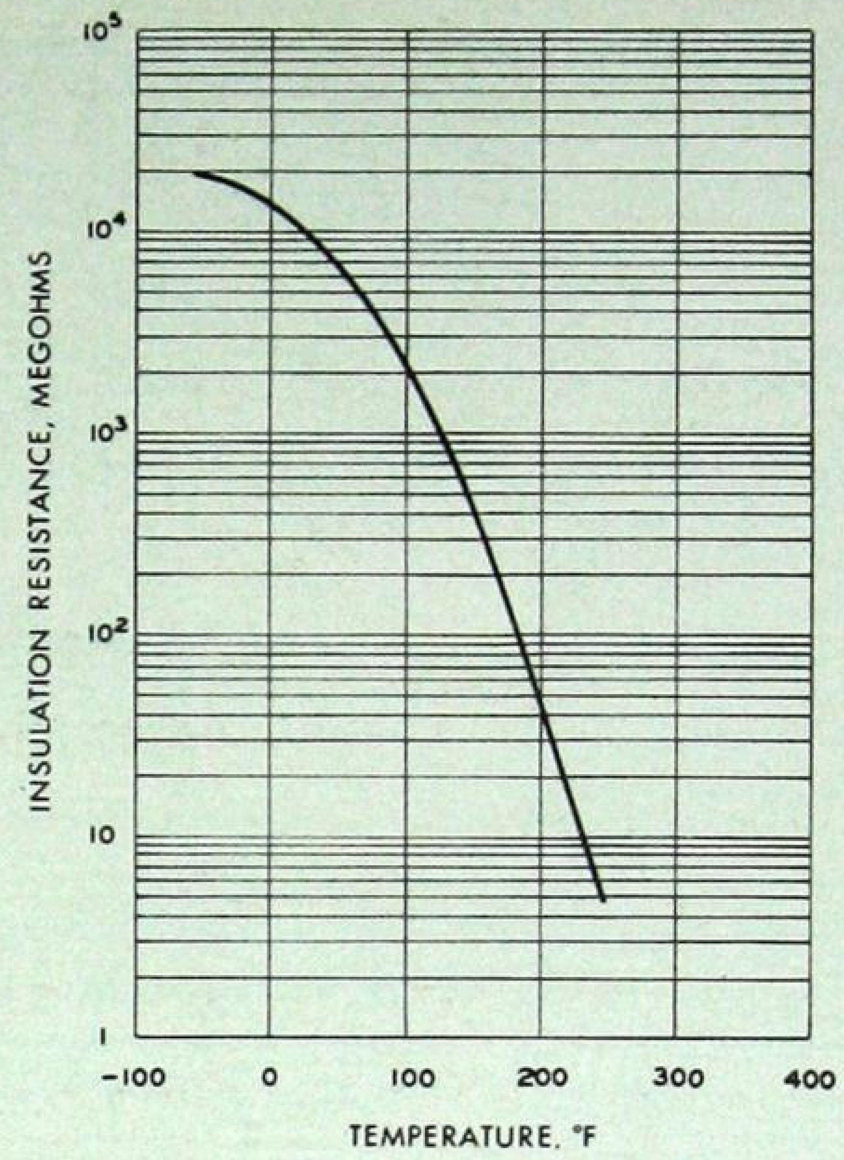


FIGURE 16—Change in Insulation Resistance of Kodapak II Sheet with Temperature (R.H. about 30%).

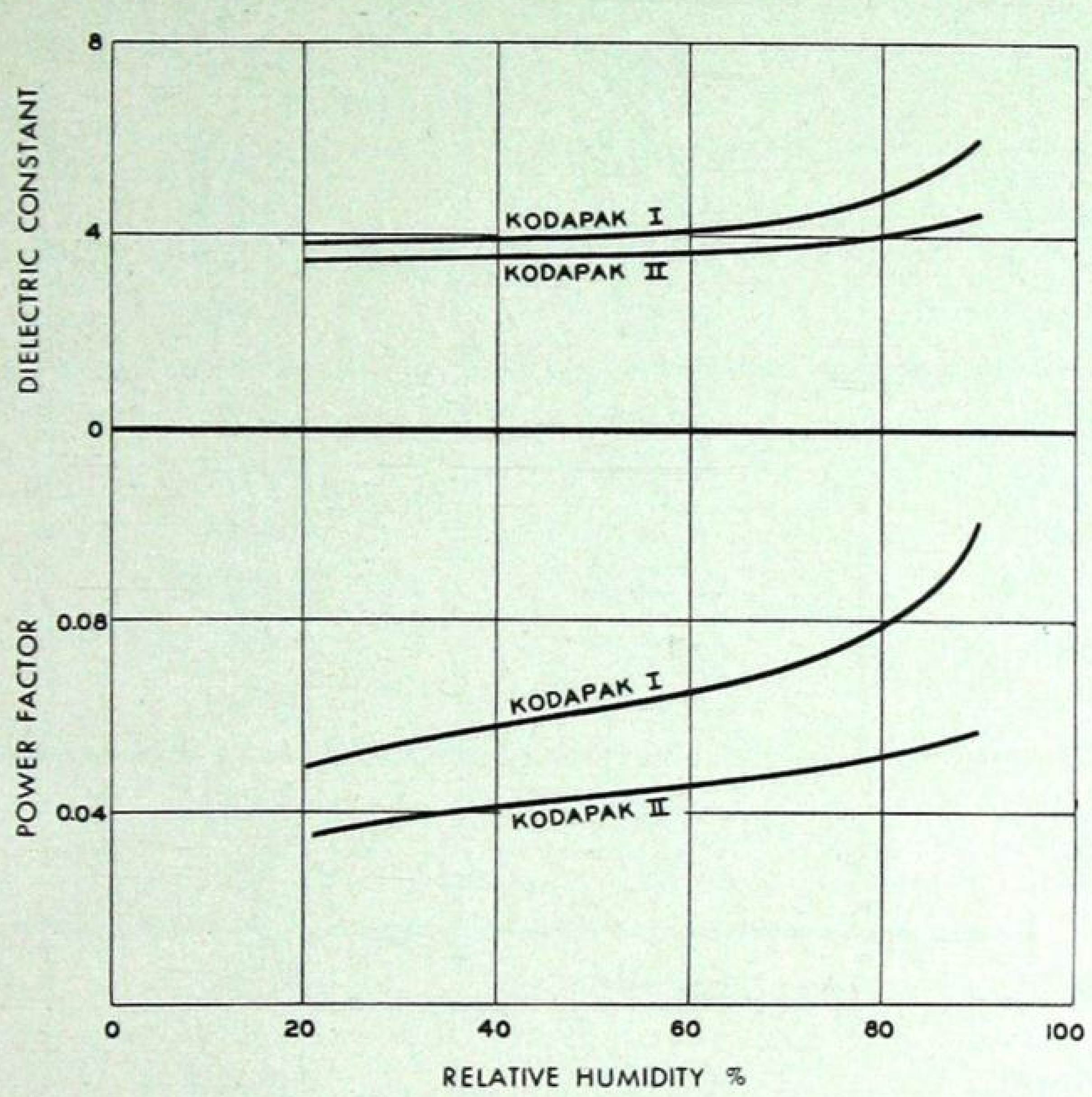


FIGURE 17—The Effect of Relative Humidity at 70° F. on the Dielectric Constant and Power Factor of Kodapak Sheet at a Frequency of 10 Megacycles.

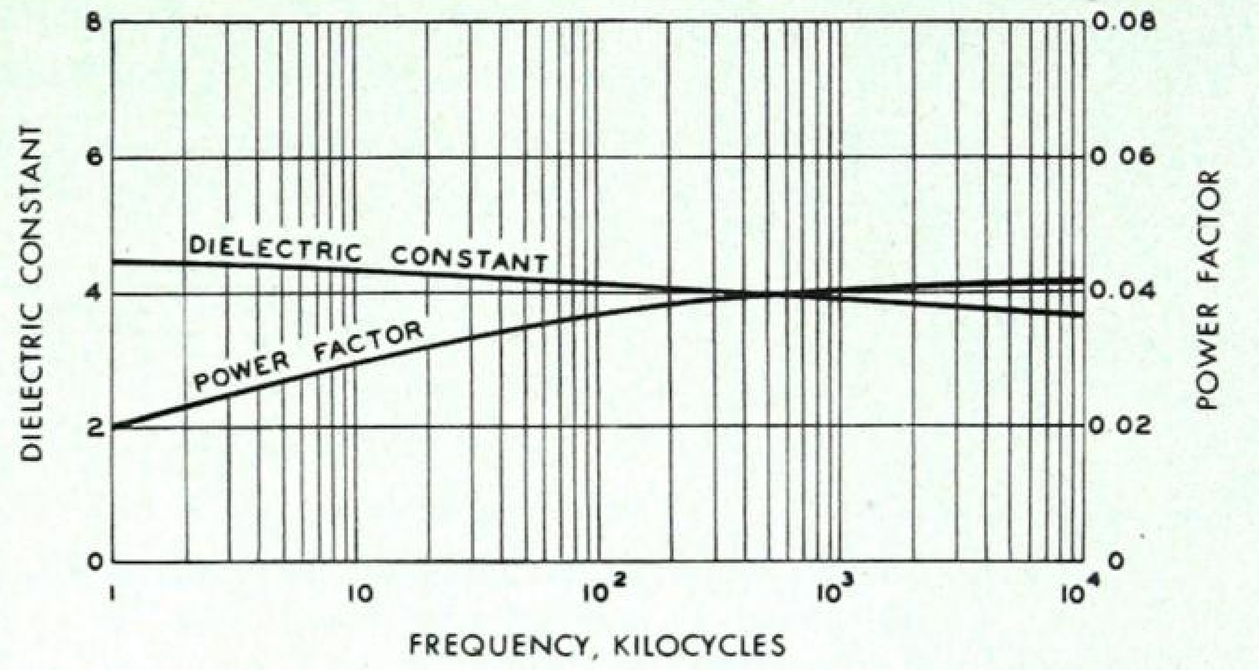


FIGURE 18—Mean Dielectric Constant and Power Factor of Kodapak I Sheet and Kodapak II Sheet at Various Frequencies at approximately 75° F., 30% R.H.

The changes in dielectric constant and power factor of Kodapak Sheet over a range of frequencies are shown in Figure 18. These measurements were obtained by a method similar to A.S.T.M. D150-46T at frequencies below 100 cycles and by means of a Q-meter at frequencies from 1 kilocycle to 10 megacycles. The dielectric constant of Kodapak Sheet decreases slightly and the power factor increases with increase in frequency.

High-Frequency Sealing

Even though Kodapak Sheet is an excellent dielectric at low and moderate frequencies, it can be dielectrically heat-sealed using power generators supplying high frequency currents at 27 to 200 megacyles or higher. If Kodapak Sheet is placed between metal electrodes of the desired shape, a bond can be made within one second or less. The amount of power transformed to heat the material varies directly as the square of the field intensity, the applied frequency, and the loss factor of the material (dielectric constant × power factor). This "deep-heat" method of bonding Kodapak Sheet offers several improvements for many fabrication processes. The illustration at the right on page 14 shows one use of dielectric heat sealing in the fabrication of boxes made of Kodapak Sheet.

FACTS AND FIGURES ABOUT KODAPAK SHEET

LIGHT GAUGES **(0.00088″ to 0.002″)**

0.001″ Gauge Tested Except Where Stated Otherwise.

	PROPERTIES	KODAPAK I SHEET (Cellulose Acetate)		KODAPAK II SHEET (Cellulose Acetate Butyrate)	
		F 116	F 120 (Rigid)	F 208	F 268
GENERAL	Specific Gravity	1.27	1.29	1.16	1.18
MOISTURE	Water Absorption, 24 hours immersion				
	Total Water Absorbed, %	8-10	8-9	4-5	4-5
	Soluble Matter Extracted, %	6-8	0	0	0
	Moisture Content at 70°F., 50% R.H., %	1.5	1.8	0.80	0.80
	Humidity Coefficient of Linear Expansion per 1% R.H. x 10^5	7.0-8.0	7.5-8.5	3.0-4.0	3.0-4.0
	Moisture Vapor Permeability 100°F., 90% R.H., gms./sq.m./24 hrs.	1500	1300	1000	1000
PERMANENCE	Weight Loss, 72 hrs., 180°F.,%	14-16	4-5	9-11	14-16
	Shrinkage in Air, %				
	24 hours 160°F.	2.5-3.0	0.25-0.75	0.5-1.0	1.5-2.5
	7 days 120°F., 20% R.H.	1.0-2.0	0.2-0.5	0.4-0.8	0.5-1.0
	3 months 70°F., 50% R.H.	1.0-1.5	0.1-0.2	0.2-0.4	0.3-0.5
	Resistance to Discoloration in Sunlight	good	good	good	good
MECHANICAL	Tensile Strength (Schopper), 10^3 psi.	9-11	12-14	7-9	6-8
	Elongation, %	30-45	20-35	60-70	60-70
	Energy to Fracture (Toughness), 10^3 in.-lbs./sq. in.	8-11	6-9	12-15	12-15
	Modulus of Elasticity in Tension, 10^5 psi.	3.0-3.5	4.5-5.0	2.0-2.5	2.0-2.5
	Modulus of Elasticity in Flexure (Taber), 10^5 psi.	—	—	—	—
	Tear Resistance (Elmendorf), gms.	3	2	4	4
OPTICAL	Refractive Index, N_d	1.49	1.48	1.48	1.48
	Transmission of White Light, %	93	93	93	93
THERMAL	Burning Rate, in./min.	100-150	70-100	50-80	70-100
	Thermal Coefficient of Linear Expansion per °F. x 10^5	5.0-6.0	4.0-5.0	4.0-6.0	4.0-6.0
	Penetration Temperature, °F.	375-425	450-500	200-250	200-250
	Heat Distortion Temperature, °F.	—	—	—	—
	Heat Forming Temperature, °F.	—	—	—	—
	Creasing and Folding Temperature, °F.	—	—	—	—
	Continuous Beading Temperature, °F.	—	—	—	—
	Deep Drawing Temperature, °F.	—	—	—	—
CHEMICAL	Effect of Chemical Reagents				
	Weight Gain in 168 hours immersion, %				
	a. Sulfuric Acid, 30%	—	—	—	—
	b. Sulfuric Acid, 3%	—	—	—	—
	c. Sodium Hydroxide, 10%	—	—	—	—
	d. Sodium Hydroxide, 1%	—	—	—	—
	e. Ethyl Alcohol, 95%	very slight	very slight	swells	swells
	f. Ethyl Alcohol, 50%	—	—	—	—
	g. Acetone	soluble	soluble	soluble	soluble
	h. Ethyl Acetate	soluble	soluble	soluble	soluble
	i. Ethylene Dichloride	partially soluble	partially soluble	soluble	soluble
	j. Carbon Tetrachloride	no effect	no effect	no effect	no effect
	k. Toluene	no effect	no effect	swells	swells
	l. Heptane	no effect	no effect	very slight	very slight
	m. Sodium Chloride, 10%	—	—	—	—
	n. Water, distilled	—	—	—	—
ELECTRICAL	Dielectric Strength-Short Time, volts/mil.	3700	3700	3700	3700
	Dielectric Constant				
	60 cycles	4.7	4.7	4.5	4.5
	10^3 cycles	4.5	4.5	4.3	4.3
	10^6 cycles	4.4	4.4	3.7	3.7
	Power Factor				
	60 cycles	0.018	0.018	0.015	0.015
	10^3 cycles	0.022	0.022	0.018	0.018
	10^6 cycles	0.051	0.051	0.043	0.043

MEDIUM GAUGES (0.003″ to 0.020″)

0.010″ Gauge Tested Except Where Stated Otherwise.

KODAPAK I SHEET (Cellulose Acetate)					
F 103 (Rigid)	F 116	F 122	F 124	TEST METHOD* (Conditions 70°F, 50% R.H.)	
1.29	1.27	1.29	1.29	A. S. T. M. D792-44T	GENERAL
6.5-7.0	6.0-6.5	6.0-6.5	6.0-6.5	A. S. T. M. D570-42 (0.002″ thickness tested for light gauges)	
0.3-0.5	1.5-2.0	0.5-1.0	0.5-1.0		
2.0	1.5	1.6	1.6	(1) page 18	MOISTURE
8.0-9.0	7.0-8.0	7.0-8.0	7.0-8.0	(2) page 18	
180	200	190	190	A. S. T. M. D830-45T	
2.5-3.0	7.0-7.5	3.0-3.5	3.5-4.0	A. S. T. M. D786-46T	
0.5-1.0	0.5-1.0	0.1-0.2	0.2-0.5	(3) page 18	PERMANENCE
0.5-1.0	0.5-1.0	0.1-0.2	0.2-0.5		
0.3-0.8	0.3-0.5	0.1-0.2	0.2-0.5		
good	good	good	good		
11-13	9-11	9-11	9-11	(4) page 18	
30-40	35-45	30-40	30-40		
10-13	9-12	10-13	10-13		MECHANICAL
4.0-5.0	3.0-3.5	3.0-3.5	3.0-3.5	(5) page 18	
4.0-5.0	3.0-3.5	3.0-3.5	3.0-3.5	A. S. T. M. D747-43T	
100-110	80-90	90-100	90-100	A. S. T. M. D689-44	
1.49	1.49	1.49	1.49	A. S. T. M. D542-42	OPTICAL
92	92	92	92		
elf-extinguishing	10-15	self-extinguishing	self-extinguishing	A. S. T. M. D568-43	
4.0-5.0	5.0-6.0	5.0-6.0	5.0-6.0	(6) page 19	
——	——	——	——	(7) page 19	
220-230	190-200	205-215	205-215	(8) page 19	THERMAL
220-290	210-280	210-290	210-290		
250-290	240-280	250-290	250-290		
230-250	220-240	230-280	230-280		
230-260	220-250	220-260	220-260		
0.7	1.4	0.7	0.7	A. S. T. M. D543-43 (0.020″ thickness tested for medium gauges)	
3.8	2.6	1.0	0.8		
52.0	47.8	40.0	34.2		
5.0	7.0	4.4	10.3		
11.3	5.0	11.4	13.4		
13.5	14.6	4.7	9.3		
soluble	soluble	soluble	soluble		CHEMICAL
soluble	soluble	soluble	soluble		
artially soluble	partially soluble	partially soluble	partially soluble		
0.9	10.0	6.6	11.3		
8.0	3.0	3.8	0.0		
0.5	0.5	0.0	1.7		
3.0	2.6	2.6	1.7		
3.6	3.2	3.5	1.5		
1700	1700	1700	1700	A. S. T. M D149-44	
4.7	4.7	4.7	4.7	Similar to A. S. T. M. D150-46T	
4.5	4.5	4.5	4.5		
4.4	4.4	4.4	4.4		ELECTRICAL
0.018	0.018	0.018	0.018		
0.022	0.022	0.022	0.022		
0.051	0.051	0.051	0.051		

*Test Methods are described on the following pages

HOW THE TESTS WERE MADE

The test methods employed in obtaining the data given in this booklet conform, as far as possible, to the standard tests for plastics of the American Society for Testing Materials. The test conditions were 70° ±1°F. and 50% ±2% relative humidity, except where stated otherwise. Tests used which are not A.S.T.M. standard methods are described briefly below.

1. Moisture Content at Specified Relative Humidity

Samples, thoroughly conditioned at a specified relative humidity and temperature, are analyzed for moisture by the Karl Fischer titrimetric method or by evacuation at room temperature (in cases where other volatile material does not interfere).

2. Humidity Expansion

Strips, approximately 1½ x 15 inches, containing two sets of standard 35mm. motion picture film perforations 10 inches apart, are conditioned thoroughly at 20% relative humidity at 70°F. The distance between the perforations is measured with a special shrinkage gauge which is accurate to 0.001″ (illustrated below). The samples are then conditioned at 70% relative humidity at 70°F. and re-measured. From the difference between the two measurements the humidity coefficient of linear expansion per 1% relative humidity is calculated.

3. Shrinkage in Air

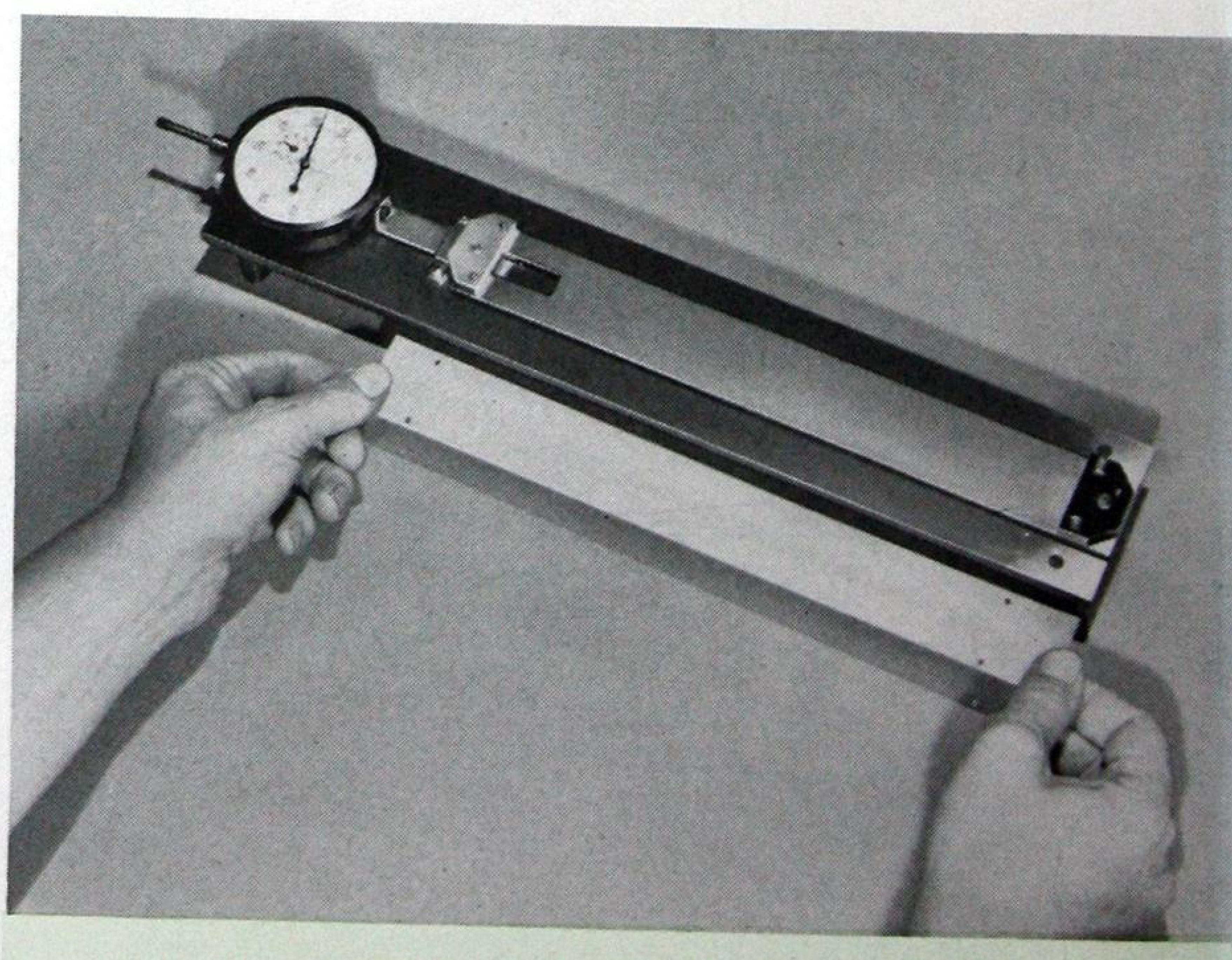
Strips, approximately 1½ x 15 inches, perforated as in the above test are conditioned at 70°F., 50% relative humidity, and measured. They are then subjected to the treatment specified, reconditioned at 70° F., 50% relative humidity, re-measured and the percent shrinkage calculated from the difference between the two measurements.

4. Tensile Strength

The Schopper tensile machine is employed, operating at a speed of 100mm. per minute. Specimens are cut 15mm. wide and of sufficient length to permit a 100mm. initial jaw separation (illustrated on the opposite page). The samples are stretched in the machine until rupture occurs; either the load and elongation at break or a complete stress-strain curve may be obtained. The energy required to fracture the specimen, which is a measure of toughness, is calculated from the area under the stress-strain curve.

5. Modulus of Elasticity in Tension

Modulus of elasticity or stiffness is given by the slope of the initial straight-line portion of the stress-strain curve below the yield point (see Figure 9, page 9) and may be computed from such a curve. A simpler and more accurate method has been devised for determining the modulus of elasticity of thin sheeting. Gauge marks are scribed 10 inches apart on specimens about 15mm. x 12 inches in size. The



This special shrinkage gauge is accurate to 0.001″.

distance between the two marks is measured, by means of a pair of shop microscopes mounted on a steel bar, before and after the application of a small tensile load to the sample. The modulus is calculated from the load applied, the elongation, and the dimensions of the specimen.

6. Thermal Expansion

With thin plastic sheets it is not possible to determine thermal expansion coefficients by means of the usual dilatometer method (A.S.T.M. D696-44). Instead, strips of sheeting about 15mm. x 12 inches conditioned at 70°F., 50% relative humidity, are sealed between a pair of glass plates in such a way that the specimens are free to expand or contract, and at the same time are held at constant moisture content. The distance between marks scribed on the samples 10 inches apart is read through the glass at a series of temperatures between -10°F. and 120°F., by means of a pair of shop microscopes mounted on a steel bar. The thermal coefficient of linear expansion is calculated from the measurements, correcting for the thermal expansion of the steel bar.

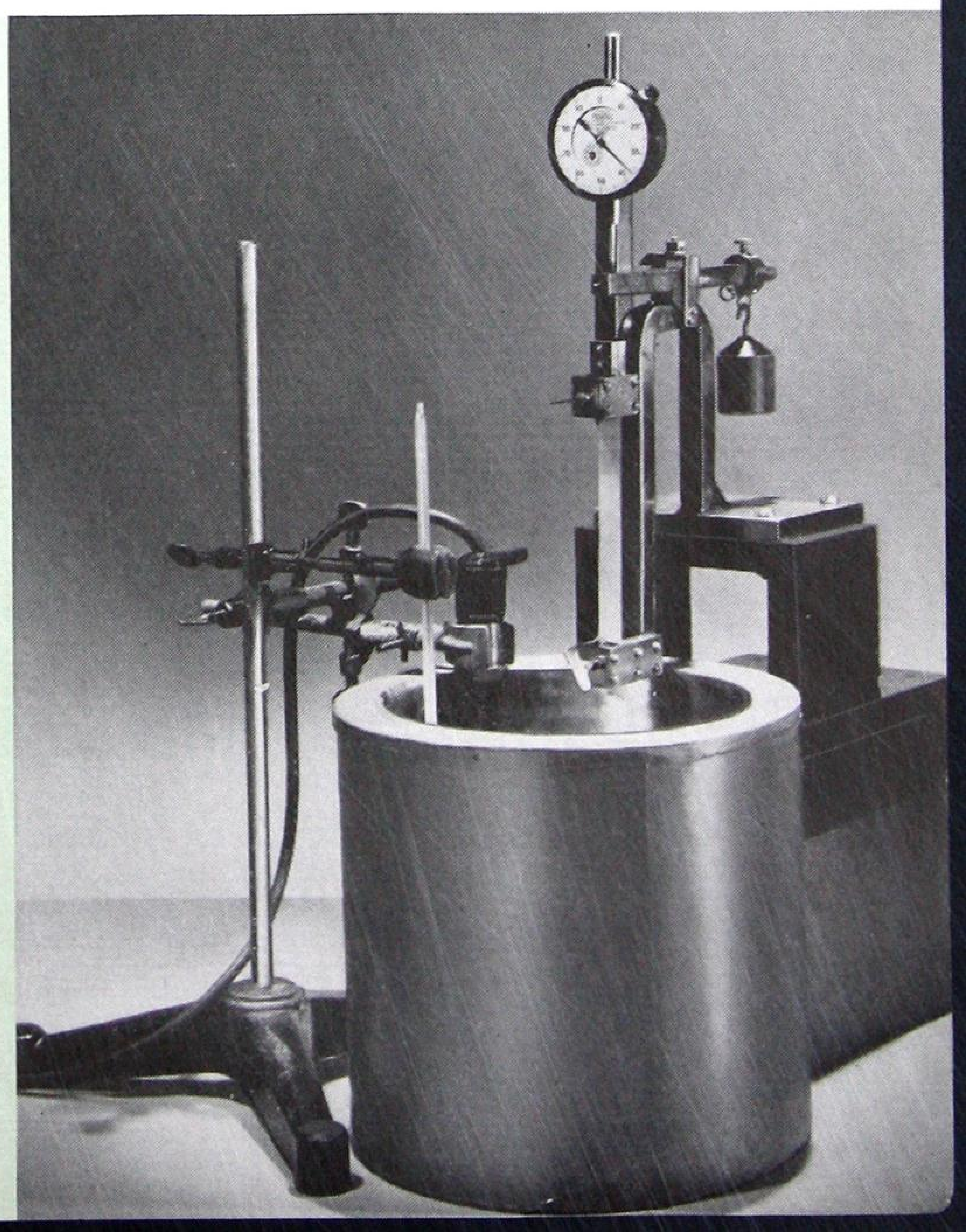
7. Penetration Temperature

This test is similar in principle to that required by U. S. Navy Specification 17-1-17, "Insulation, Electrical, Synthetic-Resin—Composition," September 1, 1945, for determining the heat resistance of very thin plastic sheet materials. A sample about 1 inch square is placed on a polished chrome-surfaced steel block. A $\frac{1}{16}''$ steel ball attached to a rod holding a 1000-gram weight is then placed on the specimen and the block heated electrically at a constant rate of exactly 5°C. per minute. An electric buzzer indicates when penetration of the sample by the steel ball occurs and the temperature of the chrome surface is determined by means of a calibrated surface pyrometer.

8. Heat Distortion Temperature

The purpose of this test is to determine the relative temperatures required to produce a given degree of distortion in thermoplastic sheet materials. The method is similar to A.S.T.M. D648-45T (which cannot be used for thin materials) except that the sample is stressed in tension instead of flexure. Strips, about 6 x ½ inches, under a constant tension of 264 psi. are heated in an inert mineral oil bath at a constant rate of $2° \pm 0.2°$C. per minute. The elongation is measured by means of a dial gauge accurate to 0.001″. (See the illustration below.) The temperature at which an elongation of 1.0% is obtained is arbitrarily selected as the heat distortion temperature. (This elongation includes some thermal expansion.) Heat distortion temperatures obtained by this procedure are of the same order of magnitude, but are not identical with those obtained by the A.S.T.M. test on molded plastics of similar chemical composition.

Measuring tensile strength with the Schopper machine. (Inset) Specimen under tension.



Special apparatus for determining heat distortion temperatures.

WEIGHT AND AREA CONVERSION TABLE FOR KODAPAK I SHEET

Outside Diameter of Roll on Standard 3″ I.D. Core	Length of Rolls in Feet for Standard Gauges											Approximate Weight of Roll, Pounds per Inch of Width
	.00088″	.00100″	.00120″	.00150″	.002″	.003″	.005″	.0075″	.010″	.015″	.020″	
4″	200	160	120	90	70	60	35	25	20	10	Preferably supplied in sheet form.	.1
5″	800	700	600	500	370	260	155	105	75	50		.4
6″	1500	1370	1200	1000	800	500	300	200	150	100		.8
7″	2800	2400	2000	1600	1200	780	470	315	235	155		1.3
8″	3700	3200	2800	2300	1700	1110	665	445	335	220		1.8
9″	5000	4400	3700	3000	2300	1480	890	595	445	295		2.4
10″	—	—	—	—	—	1895	1130	760	565	375		3.1
11″	—	—	—	—	—	2355	1410	945	705	470		3.9
12″	—	—	—	—	—	2850	1710	1140	855	570		4.7
13″	—	—	—	—	—	3400	2040	1365	1015	675		5.6
Approximate Weight, lbs./1000 sq. in. (Standard 20″x50″ or 25″x40″ sheet.)	.041	.046	.056	.069	.092	.138	.229	.334	.458	.687	.916	
Approximate Area, sq. in/pound.	25,000	22,000	18,300	14,600	11,000	7,300	4,350	2,900	2,180	1,450	1,090	
Approximate No. of Stock Sheets 20″x50″ or 25″x40″ /100 lbs.	2,500	2,200	1,830	1,460	1,100	730	435	290	218	145	109	

WEIGHT AND AREA CONVERSION TABLE FOR KODAPAK II SHEET

Outside Diameter of Roll on Standard 3″ I.D. Core.	*Length of Rolls in Feet for Standard Gauges*					Approximate Weight of Roll, Pounds per Inch of Width
	.00090″	.00110″	.00130″	.00160″	.002″	
4″	180	140	110	80	70	.1
5″	760	620	560	460	370	.4
6″	1450	1300	1100	960	800	.8
7″	2600	2200	1900	1400	1200	1.2
8″	3500	3000	2600	2100	1700	1.7
9″	4700	4100	3500	2800	2300	2.3
Approximate Weight, lbs. per 1000 sq. in. (standard 25″x40″ sheet.)	.038	.046	.055	.067	.084	
Approximate Area, sq. in./pound.	26,000	21,200	18,000	14,600	11,700	
Approximate No. of Stock Sheets 25″x40″ /100 lbs.	2,600	2,120	1,800	1,460	1,170	

HOW KODAPAK SHEET IS SUPPLIED

Rolls

Full-width (40-inch minimum) rolls are available in standard lengths, as follows:

KODAPAK I SHEET—CELLULOSE ACETATE

	Gauge	*Nominal Length*	*Approximate Weight*
No. 88	.00088-inch	5000 feet	100 pounds
No. 100	.001-inch	4400 feet	100 pounds
No. 120	.0012-inch	3700 feet	100 pounds
No. 150	.0015-inch	3000 feet	100 pounds
No. 200	.002-inch	2200 feet	100 pounds
	.003-inch	3000 feet	200 pounds
	.003-inch	2000 feet	220 pounds
	.0075-inch	1500 feet	250 pounds
	.010-inch	1000 feet	220 pounds
	.015-inch	750 feet	250 pounds
	.020-inch	500 feet	220 pounds

KODAPAK II SHEET—CELLULOSE ACETATE BUTYRATE

	Gauge	*Nominal Length*	*Approximate Weight*
No. 90	.0009-inch	4000 feet	100 pounds
No. 110	.0011-inch	4100 feet	100 pounds
No. 130	.0013-inch	3500 feet	100 pounds
No. 160	.0016-inch	3000 feet	100 pounds
No. 200	.002-inch	2200 feet	100 pounds

Rolls narrower than 40 inches are available in any width (¼-in. width, minimum), multiples of which can be cut economically from the standard-width roll.

Stock-Size Sheets

KODAPAK I SHEET AND KODAPAK II SHEET	KODAPAK I SHEET
Gauges	*Gauges*
No. 200 (.002-inch) and thinner	.003-inch to .020-inch
25 x 40 inches	20 x 50 inches
30 x 40 inches	25 x 40 inches
40 x 40 inches	

Cut-to-size sheets are also supplied.

For prices and further information write to

Cellulose Products Sales Division
EASTMAN KODAK COMPANY
Rochester 4, N. Y.

The cover of this book is laminated both sides with Kodapak I Sheet.

Front cover—From a Kodachrome transparency.

Back cover—From a Kodak Ektachrome transparency.

To learn more about

Kodapak Sheet

the Kodapak Demonstration Laboratory
in Rochester is available to demonstrate fabrication
possibilities and practical end uses

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